BOLLINGER

Earth Excavating and

Transporting Appliances

Civil Engineering

B. S.

1911

EARTH EXCAVATING AND TRANSPORTING APPLIANCES

BY

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THESIS

FOR THE

DEGREE OF

BACHELOR OF SCIENCE

IN

CIVIL ENGINEERING

IN THE

COLLEGE OF ENGINEERING

UNIVERSITY OF ILLINOIS

1911

UNIVERSITY OF ILLINOIS

May 25, 1911

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INTRODUCTION.

The subject of this thesis is indeed a broad one and if it were attempted to describe and explain in detail the operation of each machine therein contained, it would occupy numerous volumes. The machines and devices that are here treated are only those which experience and practice have shown to be appliances of worth. It has also been the aim to describe more in detail those machines which have gained especial prominence and popularity in the last few years, that is, the modern machines. Thus the dredge, steam shovel, trench machine and cableway have been treated extensively, because, by the enormity of their work, they are entitled to such consideration.

No attempt has been made to distinguish and make a separate classification of excavating and transporting machines, because, if such an effort were attempted, it would only prove futile. Nevertheless, there are machines which are used primarily for one purpose, but as a whole, their operations and work run one into the other, so that a classification is impossible. Lastly, it may be said that, while the title is extremely indefinite, so too is the task of describing, in a general way, the operations and performances of a special machine.

ROAD-MAKING MACHINERY.

The machines amd implements described in this section, while perhaps not all wholly road-making devices, will be treated as such because that is one of the principal uses for which they are employed. The problem of determining which device to use is one that deals: (1) with the distance that the material is to be transported, and (2) with the conditions of the work. The transportation of the earth is effected in the following ways: (1) Throwing with a shovel, when the distance horizontally does not exceed 12 feet, nor vertically 6 feet. (2) Wheelbarrows may be employed for distances up to 200 feet. (3) Between 200 and 300 feet two-wheeled dump carts may be used. (4) The economical limit for drag scrapers is about 150 feet; wheel scrapers may be employed up to hauls of about 500 feet. (5) When the distance exceeds 500 feet, wagons are used. (6) When the material is to be transported a great distance or dumped along a railroad track, dump cars are used.

Shovels.

The shovel is perhaps the simplest and crudest tool used in excavating earth at the present time. The work upon which a shovel can be used is extremely varied. It is employed upon railroad work,for furnace, foundry and mill purposes, contractors' uses, etc. The common shovel has either round or squared ends, with a long or short handle. The long-handled shovel is generally conceded to be the best for all around work, because the center of gravity of the laborer using it is not moved so great a distance in making the lift, and hence less energy is expended.

But still, in the case of the long-handled shovel, more energy is spent because of his shovel hand having to resist a greater moment. With the short handle this is done away with, because he grasps the handle within a few inches of the load. As a matter of fact, a beginner will invariably choose a long-handled shovel.

In loose, dry earth the square-pointed shovel will retain more of its contents during the process of raising the load, but in earth slightly damp, the round-pointed shovel is used to a better advantage, as it does not offer as great resistance in penetrating the wet lumps of dirt.

The shovel shown in Fig. 1 is the common, square-pointed, railroaders' shovel. It has a back-strap of steel which greatly strengthens the shovel in its thrust, thus enabling it to be used on heavy work. It is also used upon rock and concrete work as well as for ballasting. The round-pointed shovel, shown in Fig. 2, is the common one of this type. Fig. 3 shows shovels which are used in excavating for ditch, post, and drain purposes.

Fig. 1.

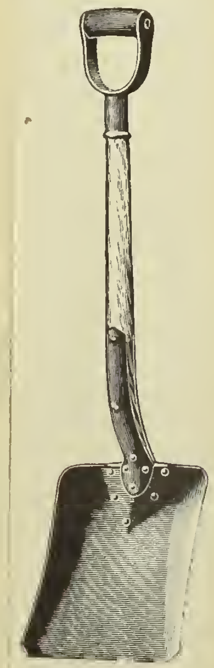


Fig. 2.

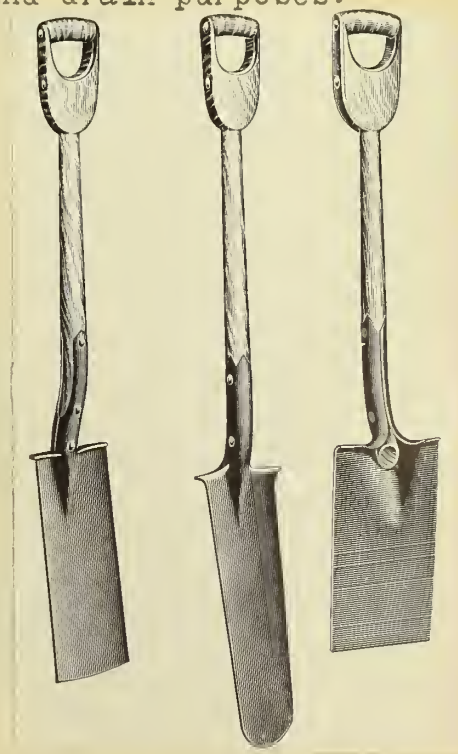


Fig. 3.

Wheel-barrows.

Wheel-barrows are adapted to many kinds of work, but their economical use is limited to narrow, confined places and short hauls.

There are many styles of wheel-barrows made, each differing in some detail, being intended for use on different work. Those used on earth-work are of the tray pattern. The frame-work is of wood, and the wheels are of steel or wood and vary from 15 to 21 inches in diameter. Naturally, the larger, the wheel the easier it is to propel the barrow, but with the large wheel the barrow sits too high from the ground for economical loading. For most purposes, a steel wheel is to be preferred, because it is made stronger than the wooden wheel, and it will generally outlast the other parts of the barrow. But, on the other hand, in case of accident, the wooden wheel can be repaired much easier than the steel one. The trays are made either of wood or steel. When only earth is being handled, the steel trays are to be preferred, as they do not sift the dirt over the runways, and it dumps easier, especially if the dirt is wet. A steel-tray barrow is shown in Fig. 4. If there is much rock in the excavation, the wooden tray gives better service and is more economical.

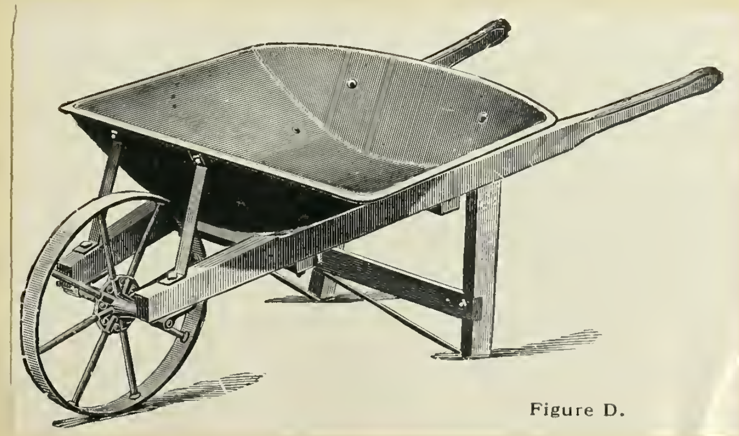


Figure D.

Fig. 4.

It is true that the steel tray will not get out of order and need repairing quite as soon as the wooden tray, but the slight difference is not enough to justify the extra cost. Steel trays cannot be as easily repaired as can the wooden trays. Extra steel trays can be purchased to put on the old running frame, but this is expensive and the steel trays likewise become dented and bent over the wheel, making it very hard to push the wheel-barrow. The wooden trays holding their shape better makes them superior for rock work.

All-steel and tubular barrows are also made, the entire barrow and running gear being of steel, but the objection to them is that they are too heavy and are also too expensive for earth excavation. Such barrows weigh from 70 to 125 pounds apiece, while steel trays on wooden frames weigh from 55 to 70 pounds, and the wooden-tray barrow weighs from 40 to 60 pounds.

Drag Scrapers.

A drag scraper is a steel scoop, not mounted upon wheels, and is drawn by a team. There are three forms of drag scrapers, the scoop, the flat-bottomed tongue or pole scraper, and the buck or fresno scraper.

The Scoop Scraper, Fig. 5, is composed of a sheet of heavy steel pressed into a practicable shape for working. Some have metal runners on the bottom, Fig. 6, and others have practically a double bottom, Fig. 7. The scoop scraper is well adapted for burrowing at the sides of embankments and for wasting material from cuts or ditches, and also for opening the mouth of large cuts. However, with the scoop scraper there is difficulty in building a bank of uniform solidity, since each scraperful is deposited in a compact mass by itself, with low, loose places between them.

Fig. 5.

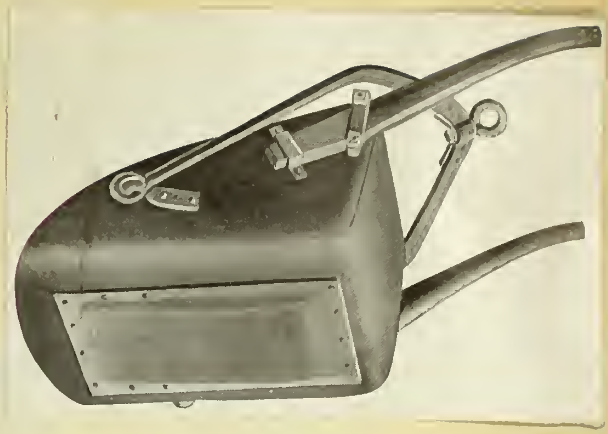


Fig. 6.

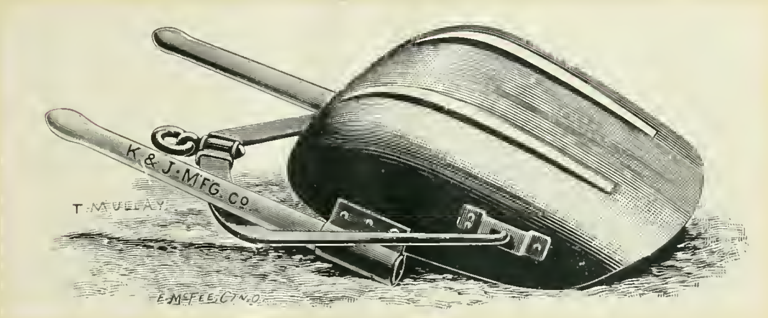


Fig. 7.

The Flat-bottomed Tongue or Pole Scraper, Fig. 8, is ordinarily used for filling ditches, leveling roads or other uneven places, and is frequently employed in preparing the subgrade for pavements. It is not, however, as convenient for general work as is the scoop scraper.

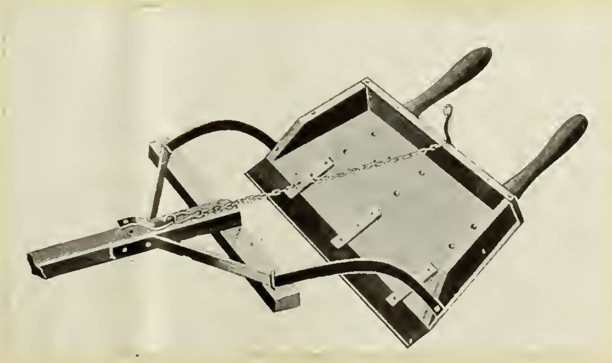


Fig. 8.

The Buck or Fresno Scraper, Fig. 9, differs from a drag scraper in being wider and having a longer cutting edge. It consists essentially of a pan, with vertical sides and back to hold the earth. To the back is attached a handle, and to the handle is fastened a small piece of rope for convenience in manipulation. When loaded, the scraper slides on the pan, but when empty, the pan tips up and rides upon the runners, in order to save wear and tear and to evade irregularities in the ground.

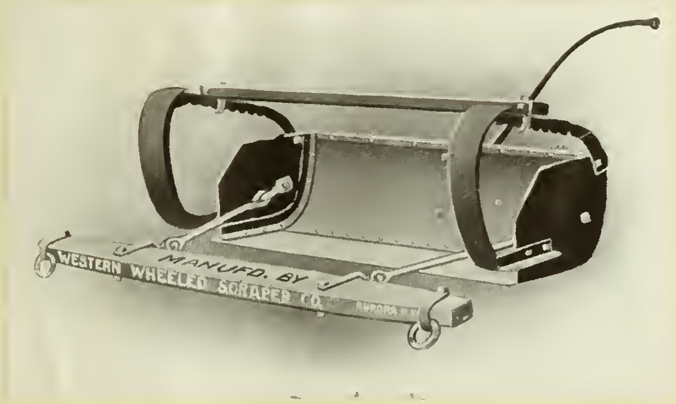


Fig. 9.

This form of scraper has several advantages over the common scoop scraper: (1) The proportions of the buck scraper are such that it is more readily loaded to its full capacity, and on account of its width an amount of earth considerably greater than the capacity of the scraper can be hauled in front of it. (2) It distributes the earth on the bank better, as it can be adjusted to deliver in layers from one to twelve inches thick. (3) The runners make it more durable. (4) It is more easily loaded. (5) It will follow up a steep bank without dumping, and hence runways are not required.

The fresno scraper is well adpated for constructing ditches, and is invaluable for leveling land for irrigation and other purposes.

Wheel Scrapers.

The wheel scraper, shown in a position to load in Fig. 10, is a development of the drag scraper; in fact, it is the drag scraper hung between two wheels. In Fig. 11 the scraper is shown in a position for dumping.

Fig. 10.

Fig. 11.

The scraper is furnished with levers for raising, lowering, and dumping, and all of these movements may be made without stopping the team. Some makes of wheel scrapers have an automatic front end-gate which adds materially to the load that it will carry, particularly on a rough, down-hill road. A good view of the wheel scraper at work is shown in Fig. 12. The work of this form of scraper is practically the same as that of the drag scraper, except that it is adapted for longer hauls.

In the majority of cases it is not so much the form of scraper used, but the generalship of the foreman in engineering the work of the excavation, that will determine the efficiency of that kind of scraper for certain length hauls.

Fig. 12.

Wagons.

A decade ago wagons were used comparatively little for transporting earth, but since then vast improvements have been made in them and in the machinery for loading them. Earth at one time was nearly always loaded by hand with shovels, but today wagons are loaded with elevating graders, with trench excavating machines, with steam shovels, and with special loading devices. In order to guide the material into the wagon bed, there have been devised various kinds of chutes and hoppers, into which the earth is first loaded. Wagons are also loaded by means of scrapers through traps, and by dump buckets or skips operated by derricks or cableways. Each of these means is governed by the conditions at hand and the kind of wagon used.

There are four types of four-wheeled wagons commonly used for earth-work at the present day; (1) the slat dump wagon; (2) the bottom dump wagon; (3) the end dump wagon; and (4) the special dump wagon.

The Slat Dump Wagon is a modification of the ordinary farmers' wagon, which was the first style of wagon to be used for earth transportation. This wagon consists of the common form of running gear, but upon the bolster of the wagon are placed 2 x 4 inch slats, and two 12 or 14 inch boards compose the sides. When the slats are all in place and the side-boards placed against the standards on the bolsters, the wagon is ready to be loaded. To unload the wagon, the driver stands at the front of it and a second man at the rear. Each grabs hold of the handles of the side-board and lifts it up and then the other is raised and finally the slats are taken out. This unloading process generally requires from two to three minutes. Slat bottom dump wagons are

only used upon excavations where the yardage is not large enough to warrant the purchase of the high-priced patented dump wagon.

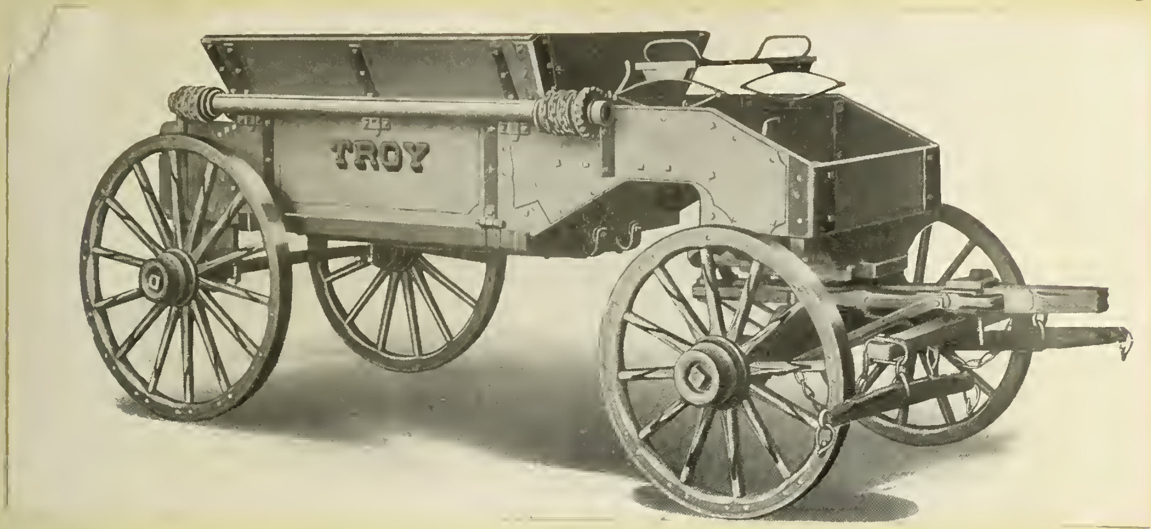


Fig. 13.

The Bottom Dump Wagon is shown ready for loading in Fig. 13. The bottom of the wagon is divided into two doors, which are hinged to the side of the wagon and join in the center of the body. These doors are of wood and are held in position by means of chains that wind around a bar. A lever and a ratchet wind up the doors to their proper position for carrying the load. This can be done by the driver while the wagon is in motion. The doors are shown swinging open in Fig. 14.

Fig. 14.

To dump the load, a lever is thrown to release a fall in the ratchet, the weight of the load thus forcing open the doors and dumping itself from the wagon body. It is not necessary to stop the wagon in dumping unless it is desired to dump all the load in some particular spot.

The End Dump Wagon is of two kinds, viz., those with tail gates and those without tail gates. The former are used for earth transportation,for dumping into hoppers or bins and through chutes, or onto scows and barges, or in railroad cars, because they are better adapted than bottom dump wagons as the horses can be backed up to the dumping place. A wagon of this design is shown in Fig. 15.

Fig. 15.

Those without tail gates generally have the bodies built of steel, and the body is built of such a shape that the load is discharged by gravity when the wagon bed is tilted for dumping. One advantage that this style of wagon possesses is that none of the load can spill or leak out unless too much of a load is placed

upon the wagon. This style of wagon is not often used for earth excavation, as the wagon is quite heavy, and owing to the shape that is given it so it will dump, its carrying capacity is reduced.

Of the Special Dump Wagons there are many types which are now in use in different sections of the country. They are either designed for special work or to suit special dumping arrangements. Some dump through the bottom, some turn over in dumping, and others must be used with special dumping apparatus or must be dumped by means of a derrick or cableway.

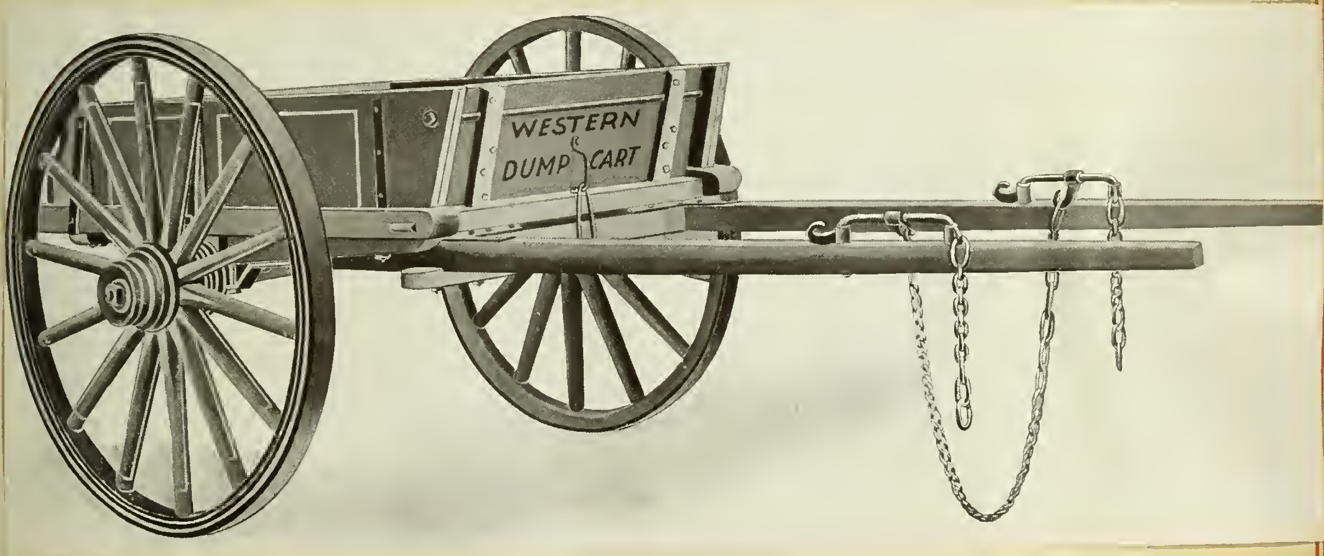


Fig. 16.

The Two-wheeled, One-horse Cart, Fig. 16, while not properly a wagon is used for the same purpose. It is employed chiefly upon grade work. Its principles of operation are the same as those of the end dump wagon.

Scraping Grader.

The scraping grader, or road machine, Fig. 17, consists of a frame carried on four wheels, supporting an adjustable scraper-blade, the front end of which plows a furrow while the rear end pushes the earth forward and distributes it uniformly in order to form a smooth surface. The blade can be shifted quickly and easily from side to side and can also be tilted backward or forward. The rear wheels can be extended as shown in Fig. 18, thus giving the blade a wider scope in its movements.

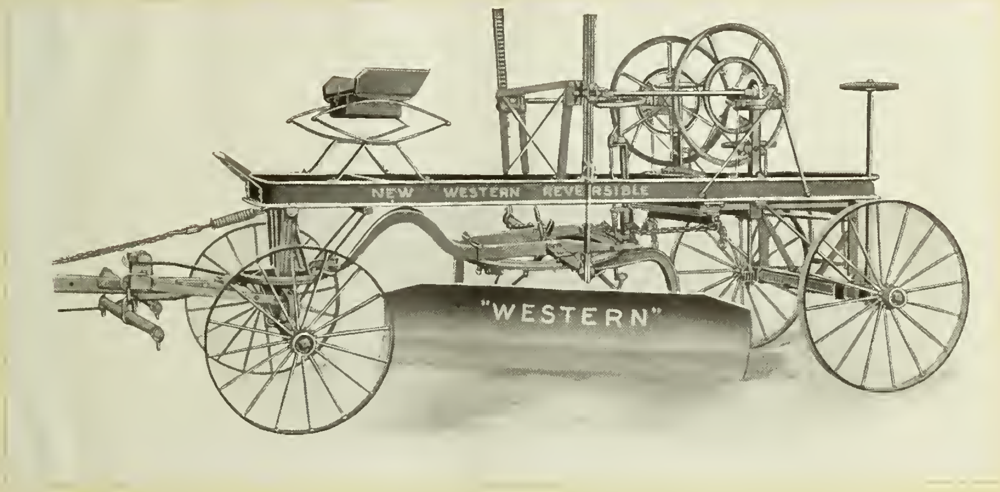


Fig. 17.

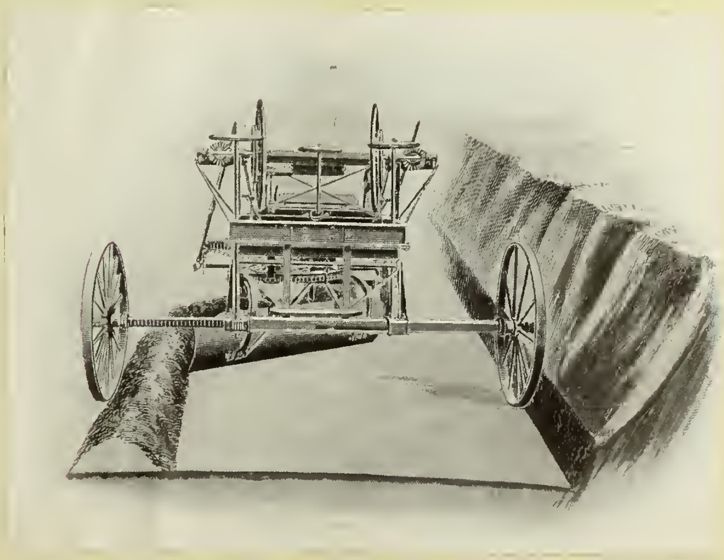


Fig. 18.

All the movements of the grader can be operated by the hand-wheels and levers on the frame. The scraping grader will work in almost any soil, even where a plow will not. It is hauled by four horses and makes successive rounds or cuts until the desired depth of ditch is obtained.

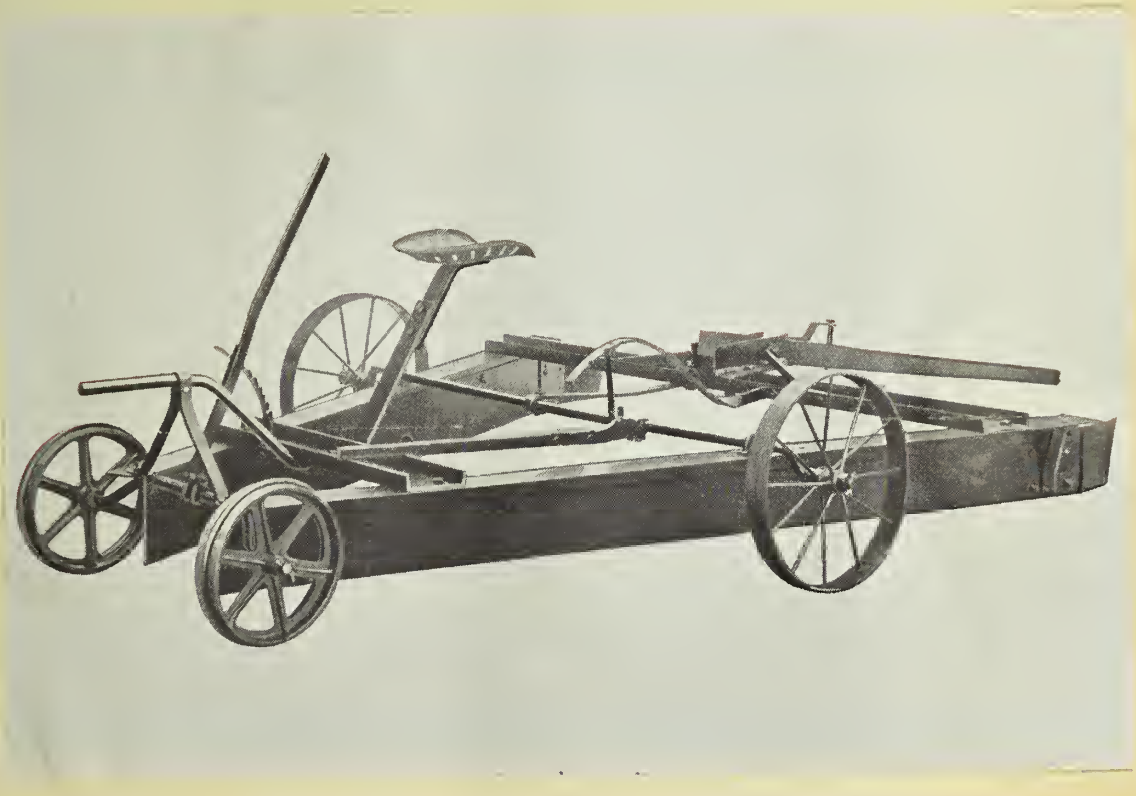


Fig. 19.

A modification of this machine is shown in Fig. 19. It consists of a V-shaped frame made of steel angles and channels mounted upon four small wheels, and to this frame are bolted the steel cutting blades. When in operation the machine shears off the high places, depositing the material in the ruts or holes and gradually works all the surplus toward the center. It is shown in operation in Fig. 20-a.

Fig. 20-a.

Elevating Grader.

The elevating grader, Fig. 20, consists of a frame resting upon four wheels, from which is suspended a plow and a frame carrying a wide traveling belt. The belt elevates the material and deposits it into wagons that are driven alongside. The plow is of the moldboard type and can be adjusted so as to be always level no matter in what position the machine may be. A grader equipped with a disc plow is shown in Fig. 21. The disc plow is best adapted for use in sand or gravel but cannot be used with advantage in work among stones, stumps or roots. The grader is hauled by horses, and an automatic attachment propels the endless belt conveyor, but in some cases the machine is equipped with a gasoline engine attachment for driving the elevator, Fig. 22.

The work of the elevating grader consists of excavating for canals, ditches, and reservoirs, in loading wagons, building

levees and embankments, throwing up roadways, etc. Views of the machine at work are shown in Fig. 23 and Fig. 24. The grader cannot, however, work to an advantage in a confined place because of the space necessary for it to turn around, and also for the wagons which receive the earth from the traveling belt.

Fig. 20.

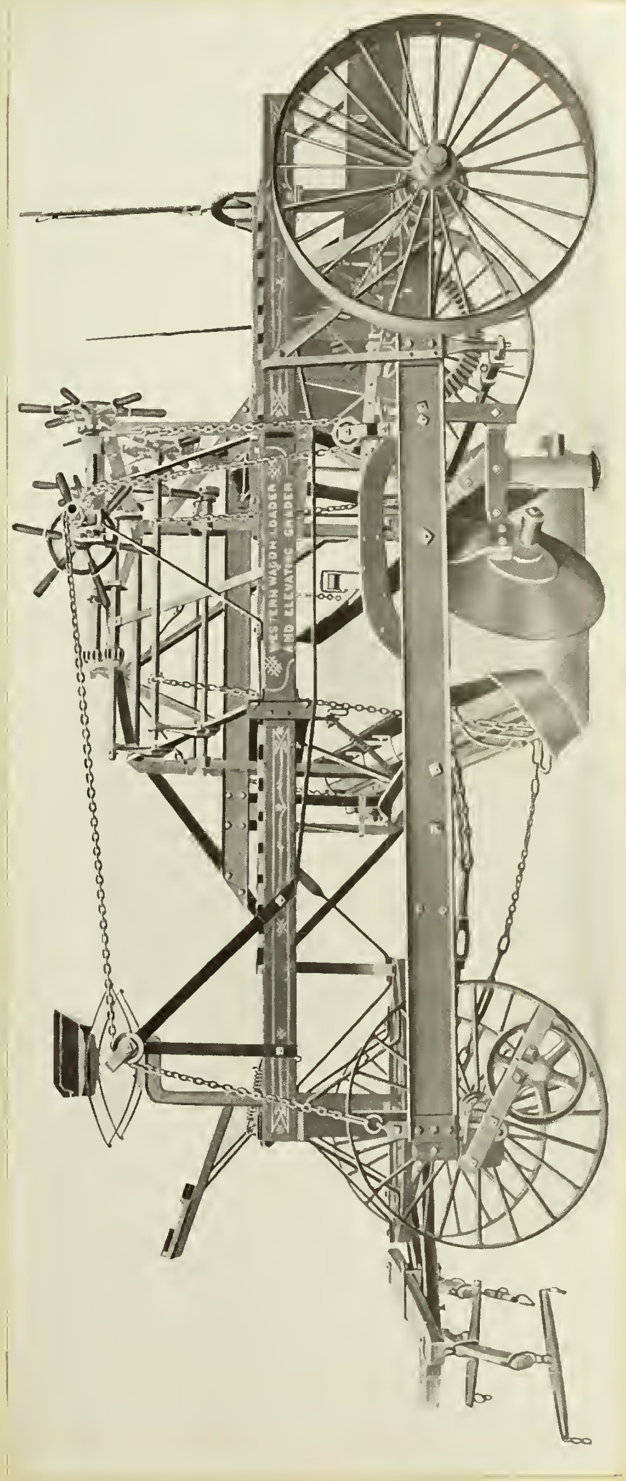


Fig. 21.

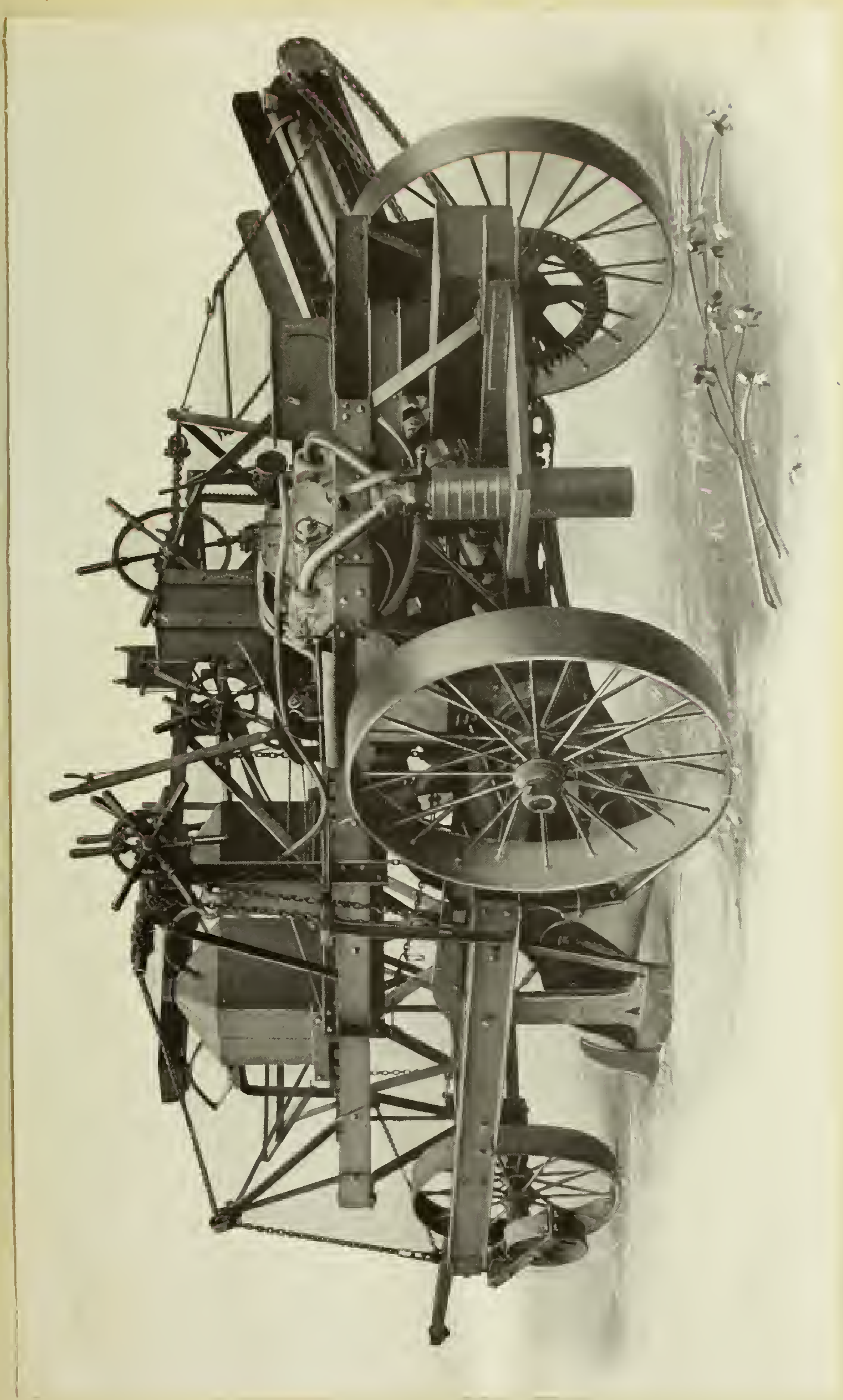


Fig. 22.

Fig. 23.

Fig. 24.

Dump Cars.

Dump cars are employed in transporting large quantities of earth a considerable distance. In the past few years there have been vast improvements in the manufacture of these cars. The old style of car, commonly known as the square box, side-door, wooden car, is fast becoming antiquated in its use. The reason of this is that an enormous amount of labor is required to unload the car. Of the modern cars, there are but three general styles, the side dump, the bottom dump car, and the common flat-car.

The Side Dump Car is shown in three positions in Fig. 25, 26, and 27. As can be seen from the illustrations, the bed of the car is pivoted longitudinally in the center over the draft beams, and hence can dump to either side. The arms which operate the doors act automatically and are pivoted,both where attached to the door and to the bed, in such a manner that as the bed is tilted the doors are thrust outward and upward from the load, so that no part of the load is thrown against the door. This arrangement tends to remove the action to derail the car by the impact of the earth. The dumping of the car, as well as bringing it back to its carrying position is accomplished by means of compressed air controlled by the engineer in his cab. Views of these cars at work are shown in Figs. 28 and 29.

The car on the right in both of these illustrations is the spreader car which follows up the dump cars and spreads the material which has been dumped by them. A more distinct view of the spreader is shown in Fig. 30. When in transportation, the blades can be raised and held alongside the car where they are out of the way.

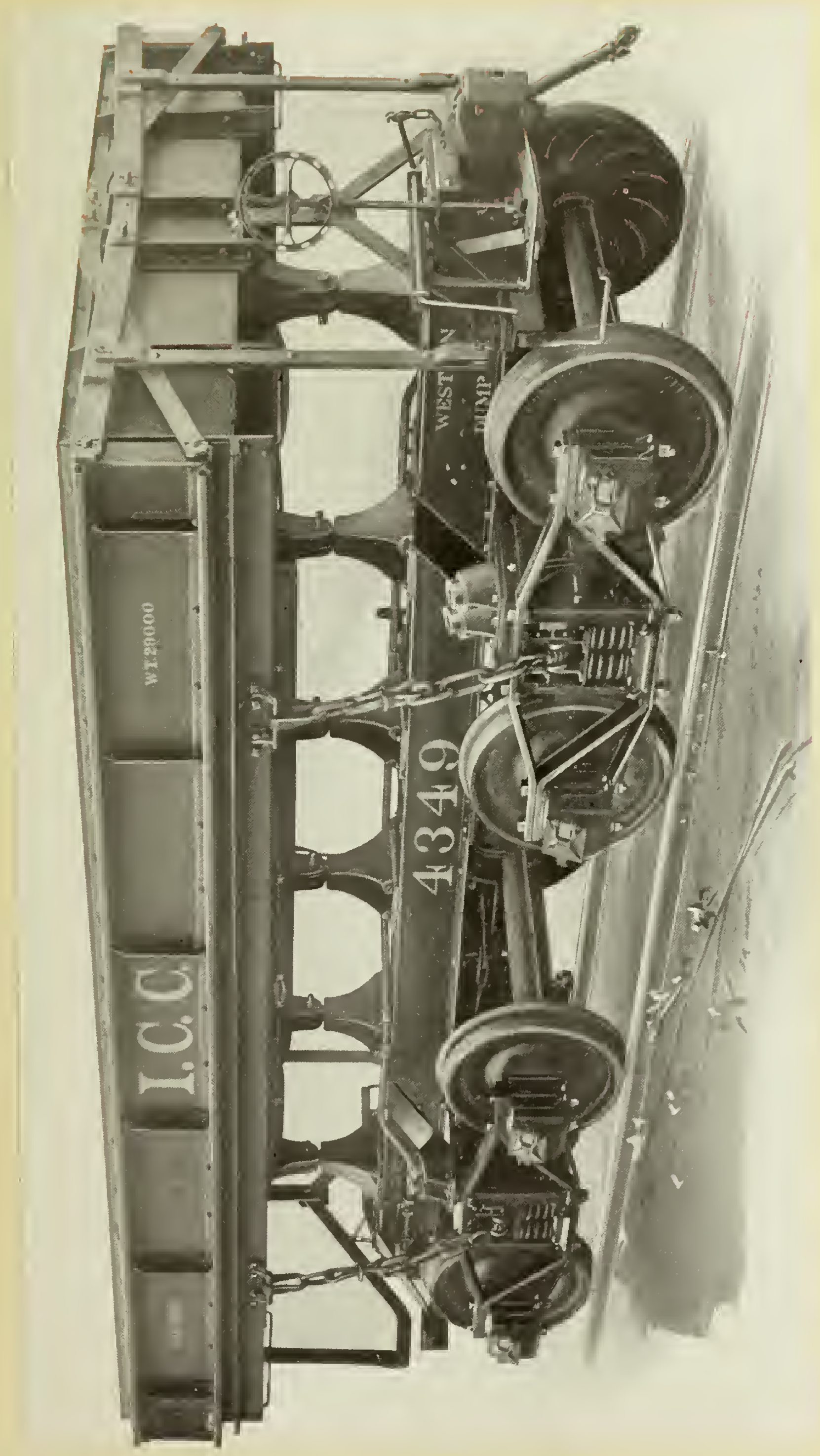


Fig. 25.

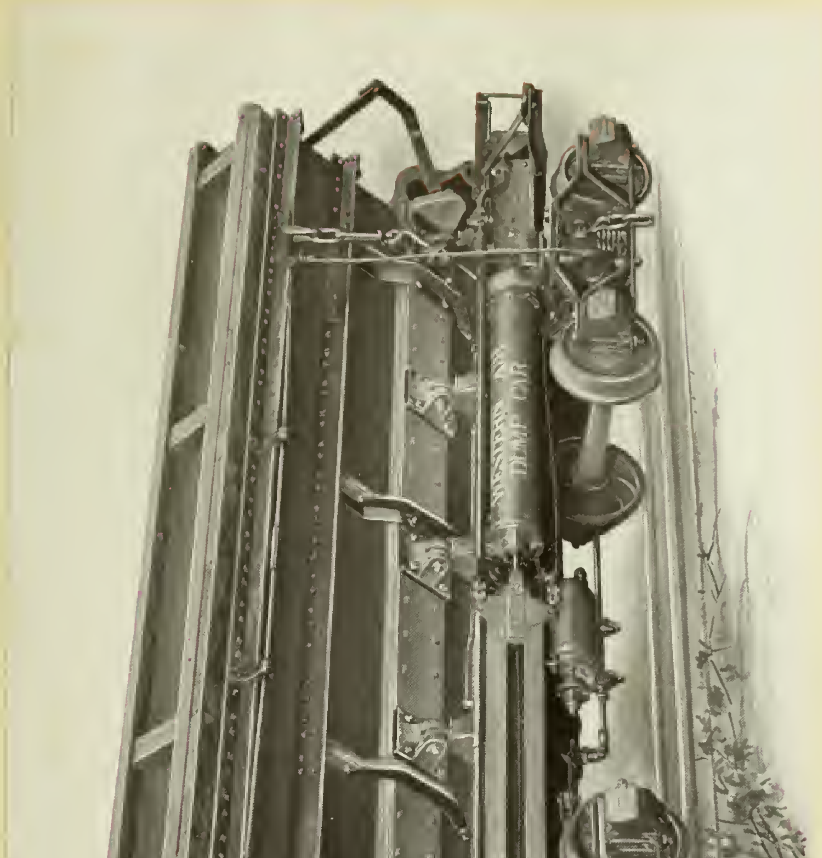


Fig. 26.

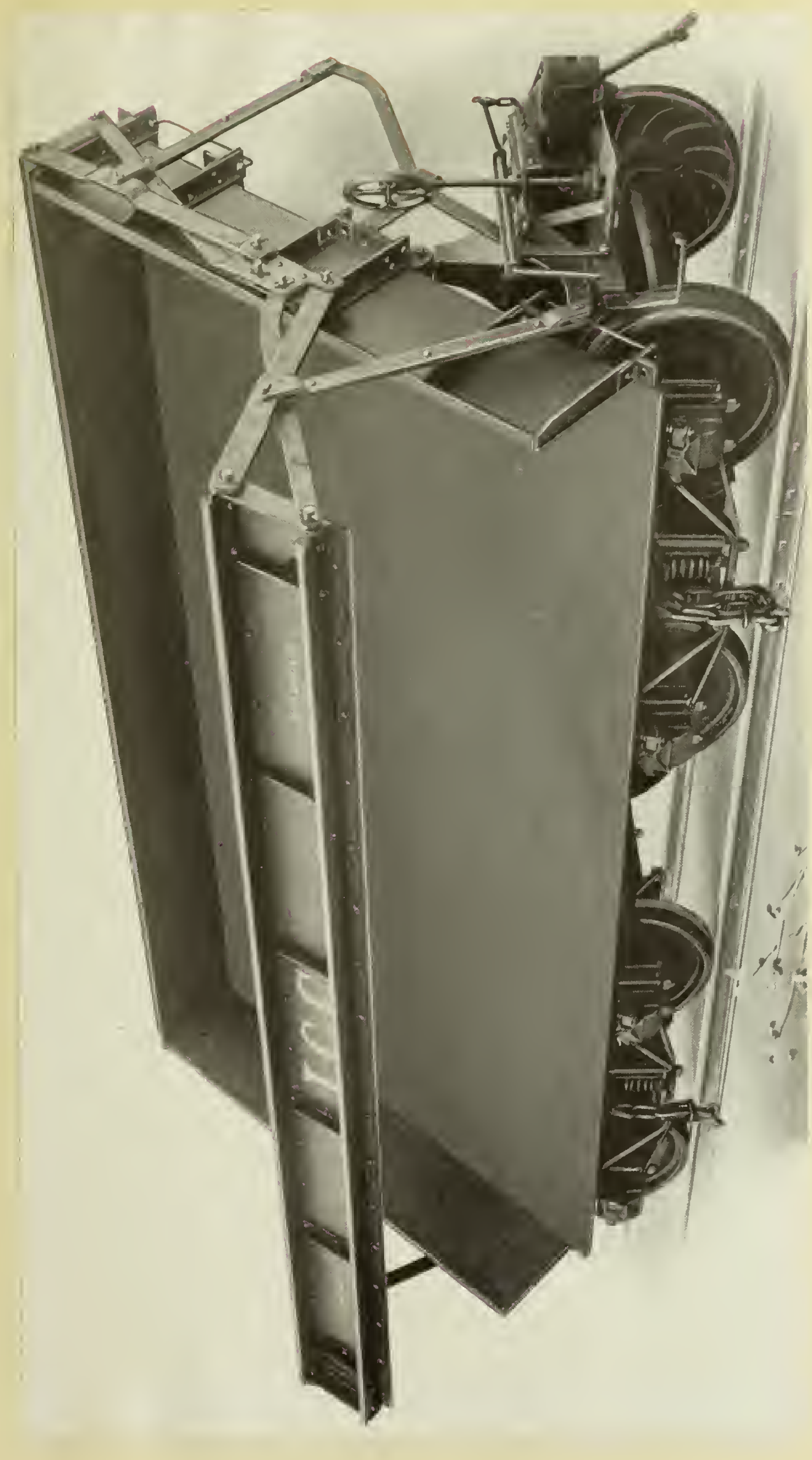


Fig. 27.

Fig. 28.

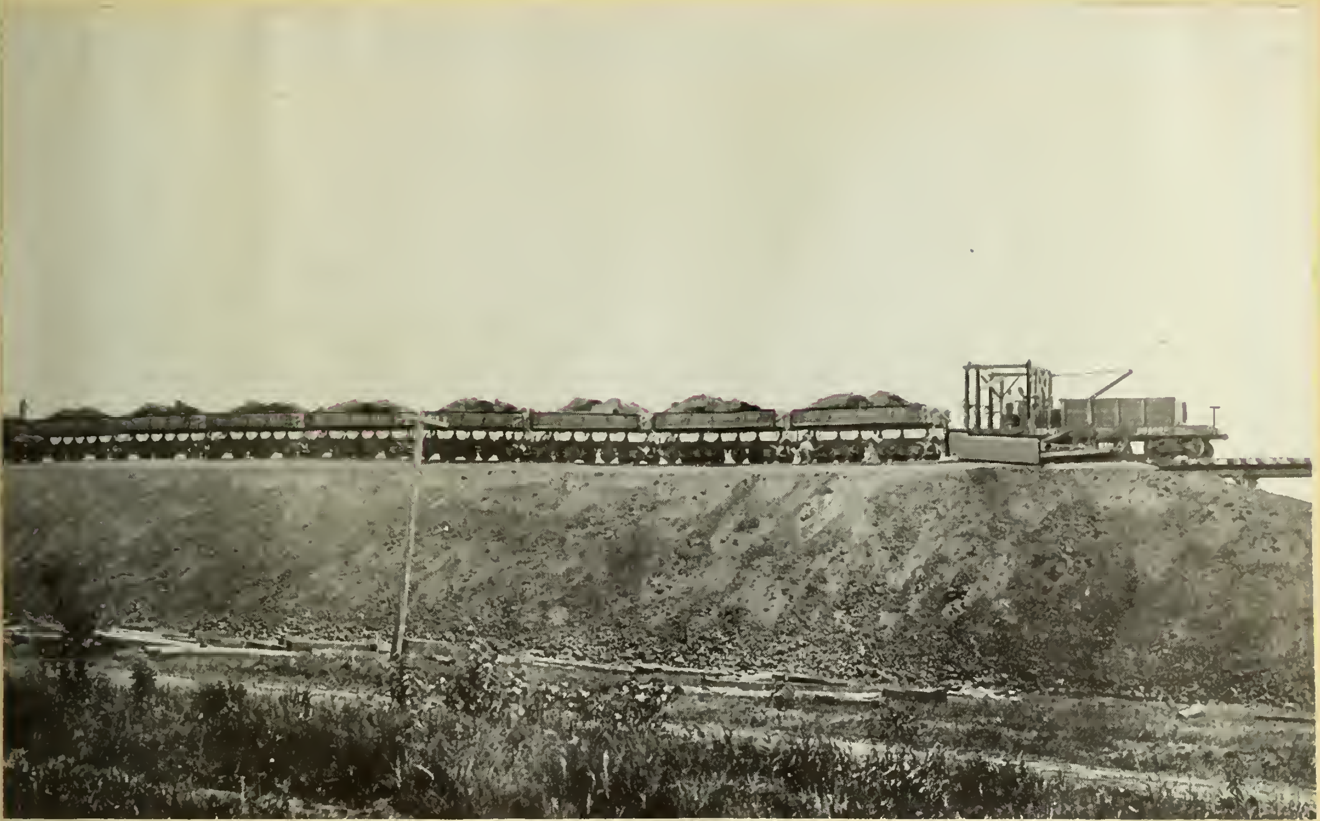


Fig. 29.

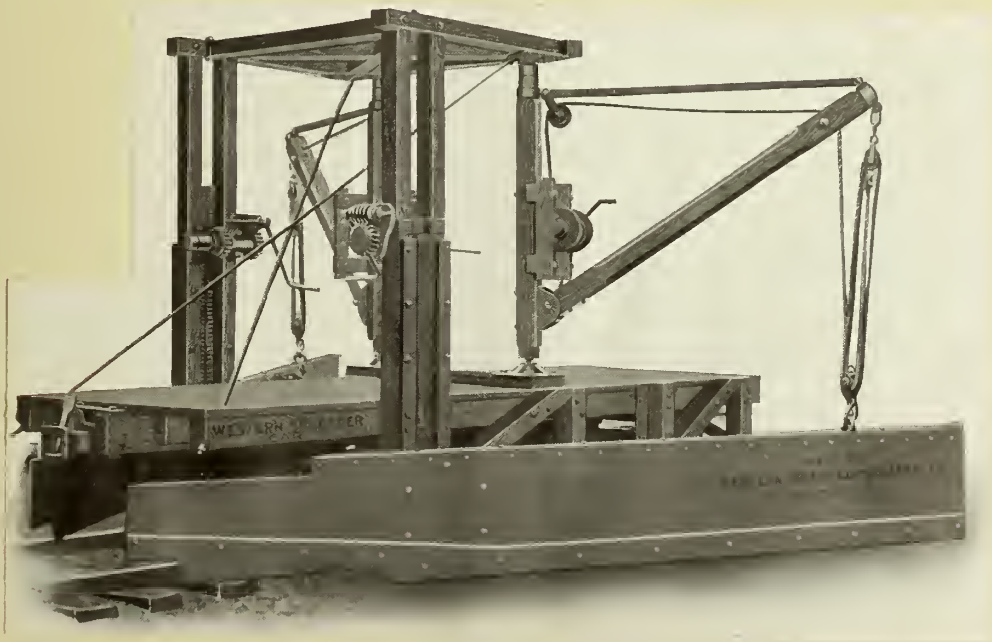


Fig. 30.

A modification of the side dump car is the rotary dump car, Fig. 31, which is capable of dumping over the end or either side. The rotating device consists of two circles, one above the other, between which play the rollers which are attached to steel rods radiating from the center

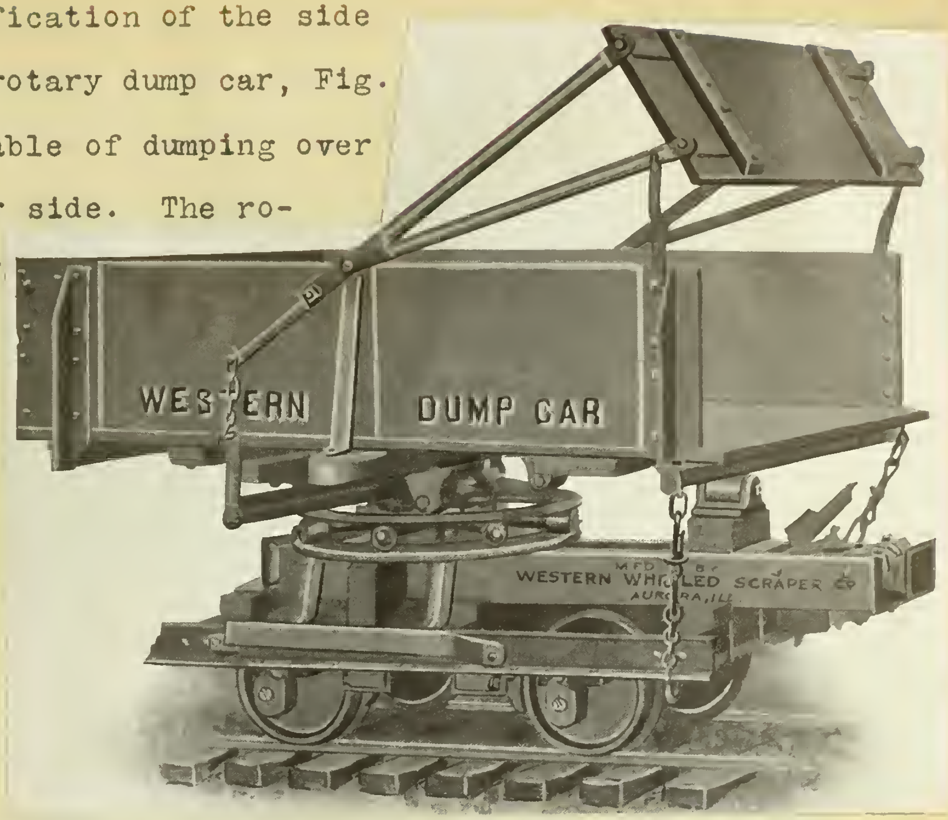


Fig. 31.

of the circles. The rotary dump car is more particularly useful at the ends of trains, where it is desired to dump over the edge of an embankment or through a trestle.

The Center Dump Car, Fig. 32, is used for depositing material through the center of the track, as for purposes of ballasting and new road construction. The dumping of the car is controlled by a hand-wheel upon one end. The amount of material dumped at a time is regulated by the width of the opening and the car can be dumped while in motion

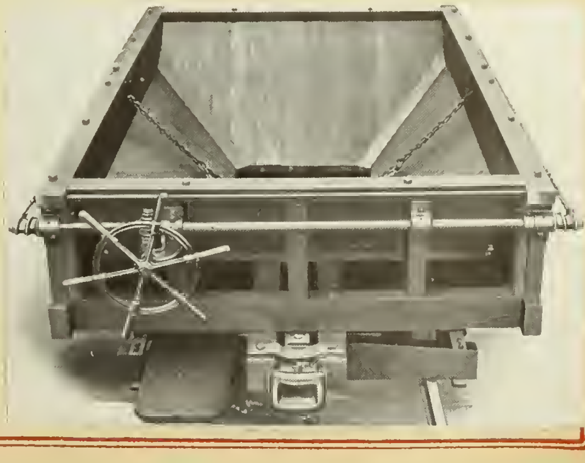


Fig. 32.

The Flat-car, while not a distinctive dump car, has grown immensely popular with contractors because of its lightness and cheapness. The car itself is simply a wooden bed set upon the trucks of the wheels. While it is extremely easy to shovel the material from a flat car that is not the manner in which the car has gained its great popularity. It is, however, the flat-car plow that has made dumping with a flat-car so economical.

The flat-car plow is either of the center, Fig. 33, or side, Fig. 34, design. The center plow is composed of two main parts, the rear or plow itself, and the forward or guiding part of the plow.

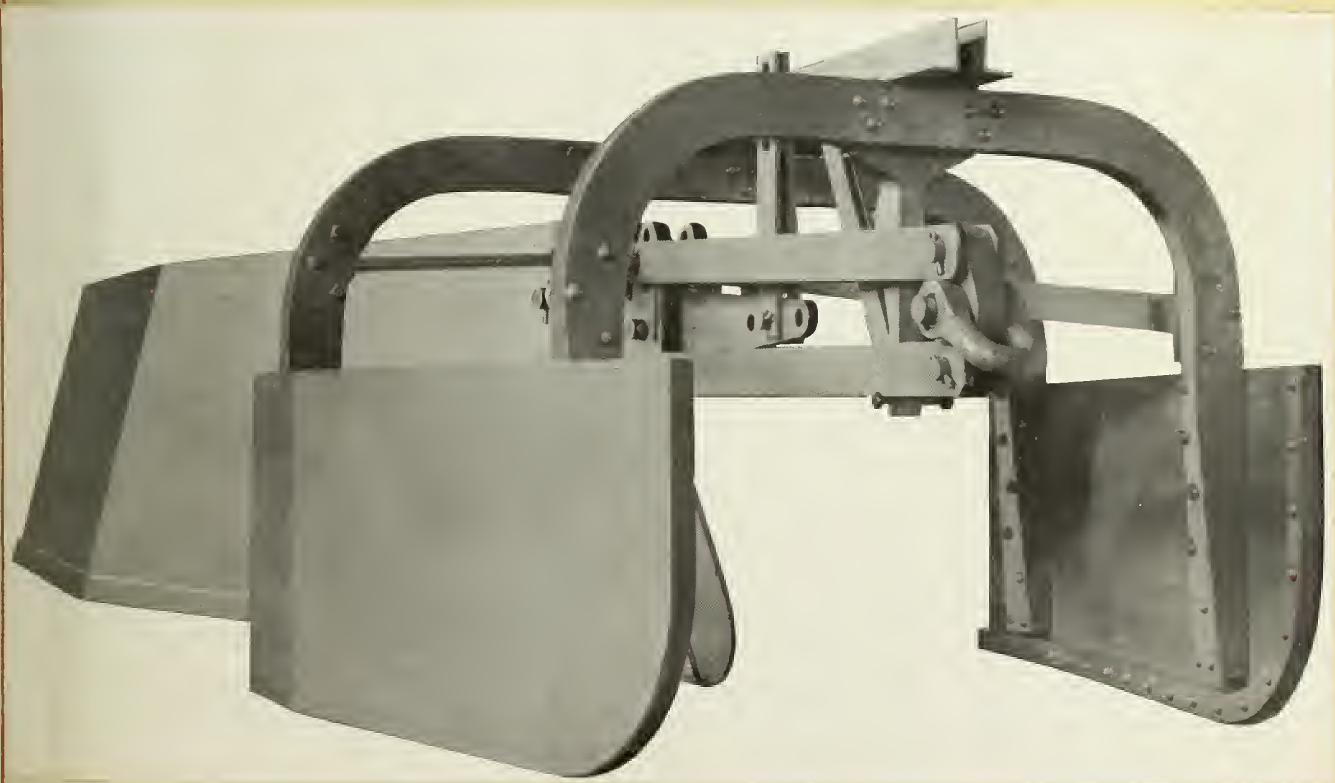


Fig. 33.

This plow is of extra heavy design because it frequently works in large blasted rock as well as in gravel and clay. The principle of the side plow varies little from the ordinary plow,

except that there is no vertical curve in the moldboard and hence the material is only pushed forward and not turned over. Both the center and side plows are pulled forward on the flat-cars by a cable attached to the engine and which is pulled ahead by the engine advancing.

Fig. 34.

Plows.

The plow is primarily an agricultural device, since in that line it receives its greatest use. The plow of today is a vast improvement over the ancient one which was designed to simply break and stir the soil. The popularity and general usefulness of the plow upon agricultural work has caused it to be used to a great extent today upon excavating work in general.

Plows may be classified according to the nature of the work which they perform: (1) agricultural plows; (2) ditching plows; (3) road plows; and (4) gang plows. Of the agricultural plows, there are four distinct types. These, however, differ only in the form of moldboard used, as that is especially designed to perform a certain class of work. (1) The sod plow has a moldboard

which completely turns the earth and buries the top layer. (2)The stubble plow simply breaks up the earth and turns it upon edge. (3) the general purpose plow is a combination of these two and is used more upon general work, as its name implies. (4) The deep tilling plow is one of recent invention and is designed more especially to excavate a deep furrow.

The ditching plow has a well-rounded moldboard and turns the earth completely. The road plow is simply designed to loosen the earth so that it can be conveniently picked up by drag scrapers. The gang plow is simply two or more of the above plows attached together. The gang plows are not very wide, being only 12 or 14 inches, while the single plow is about 18 inches wide.

Fig. 35.

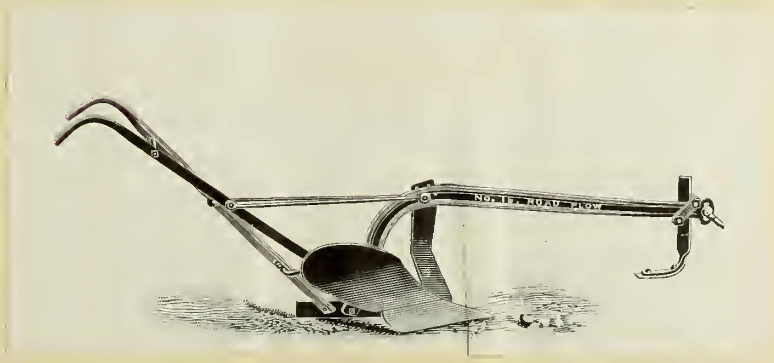


Fig. 36.

The essential parts of the plow, Fig. 35 and Fig. 36, are the share, which cuts the earth; the moldboard, which turns it; and the beam which carries these two. The plow is built very heavy because of the hard usage which it must undergo.

The work consists in grading, excavating, deep ditching or leveling in any difficult place where great strength is needed in the excavator. It can be used in rooting up hardpan, cemented gravel, rock, macadam, and frost, and, in fact, can work in any material that can be picked.

STEAM SHOVELS.

The steam shovel, or steam excavator, is a modified form of the dipper dredge and is adapted for excavating material on dry land. It was originally designed and patented by a Mr. Otis in about 1840, and the first machine was indeed a very clumsy affair. This machine, even in its crude state, possessed many advantages for removing large masses of material and its merits were soon recognized. Improvements, with increased experience in operation, were then,made which rendered it almost indispensable on all works requiring large quantities of excavation.

It was not until about 1865, however, that the machine came into general use. About this time the largely increased railway construction created an active demand for the steam shovel. This demand was further increased by the enormous amount of excavation that had to be done in such a short length of time, both in the line of railway construction and in various other works that were in progress at that time. There has been a continual demand for greater power and capacity in almost every line of work, and in this respect the steam shovel is closely following the locomotive and the steamship. Ten years ago the steam shovel, ordinarily in use, weighed 30 to 35 tons, and had a dipper of one and one-half cubic yards capacity. The shovel of today weighs 70 to 80 tons and has a dipper of anywhere between one-half to ten cubic yards capacity.

The development of the steam shovel, which is almost exclusively an American machine, has evolved a machine of great strength and speed. In the earlier shovels all the motions were performed by one pair of engines, friction clutches being employed.

This has recently been abandoned in favor of independent engines for each motion so that they can be performed simultaneously and without interruption or delay. The majority of steam shovels now in use employ a three-part chain for hoisting. For the high power and high speed now required with heavy chains, the same difficulties occur as with the chain hoist in the dipper dredge, that of excessive weight and increased friction.

The number of manufacturers of steam shovels that are upon the market today, is many, but the principal makes may be said to be the Atlantic, Bucyrus, Marion, Vulcan, and Thew. These different machines vary in distinctive designs of various parts, but the principles of operation are essentially the same in all. And of these the Atlantic may be said to be a very representative type, and its construction and operation will be described here, while various views of the several types of the different machines will be shown.

The Atlantic steam shovel, built by the Atlantic Equipment Company, of New York City, is the design of Mr. A. W. Robinson, M. Am. Soc. C. E. Mr. Robinson is a man of great renown as a civil engineer and it was he who designed the "J. Israel Tarte", the hydraulic dredge which holds the world's record for capacity and efficiency. The general construction of the steam shovel will be noted from the various following illustrations.

In Fig. 37 it will be seen that the hoisting engines are incorporated in the base of the boom so that the whole hoisting machinery revolves together. This mounting of the hoisting engines directly upon the boom renders guide sheaves unnecessary, and the power is applied in the most direct and simple manner and with the least possible loss. The hoisting engines with drum

and gearing take up very little room and the engines can pull the required amount on the dipper with a speed of five to six dipper-loads per minute. The hoisting drum is very short and of large diameter and fits easily between the sides of the boom which constitute the frame. The gearing is of steel and amply strong to stop the engines with full head of steam.

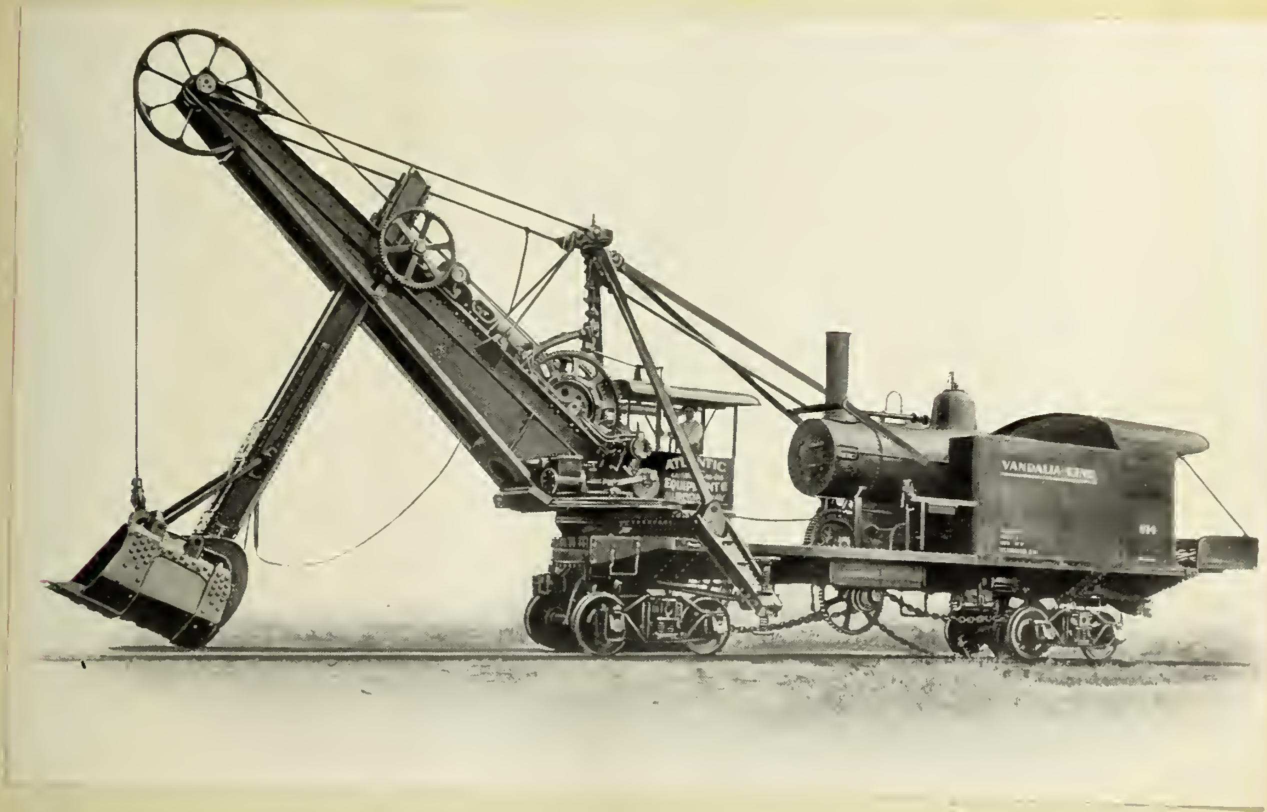


Fig. 37.

The A-frame is formed of solid steel bars having solid forged pin-connections at the foot and a cast-steel head. It is stepped upon the ends of the jack-arm truss in such a way that it forms a continuation of the jack-arms, thus giving great stability and relieving the car-frame from excessive strains.

The boom is built of structural steel shapes and is made with a straight taper, deepest at the inner end. This form is the simplest and most direct that could possibly be devised,

and gives the greatest strength where it is needed and the least weight at the outer end where there is the greatest motion. For the latter reason also, the principal weight of the boom is at the inner end on the axis of revolution, where it offers no resistance to rapid swinging. As can be seen from Fig. 38, the turntable is built solid with the boom, being made of stiffened steel plates and a rolled rim. The turntable and boom as a unit have perfect freedom of action, being separate from the revolving collar on the base.

Fig. 38.

The entire frame of the engines is of cast-steel, in one piece, and forms the foot of the boom and the center of the turntable as well. While the weight of the engines and gearing is not great, it is located on the axis of rotation of the boom and therefore does not appreciably increase the power required for swinging, nor does it interfere with the speed. The location

of the engines on the boom presents several important advantages, viz.; (1) It permits direct lead of the hoisting rope without the interference of any guide sheaves and consequent wear; (2) It leaves the car free with ample space and room for a long and efficient boiler; (3) The weight of the hoisting machinery in the base of the boom is more effective for counterbalancing the weight of the loaded dipper in side position than if back of the car; the jack-screw being the fulcrum, this weight balances the shovel against overturning; (4) The weight of the shovel, when dismounted for transportation, is more evenly distributed, the boom with its engines being loaded on a separate flat-car.

The main engines are of the locomotive type without cylinders. A sheet-steel casing is provided for protection. They have a solid cast-steel frame for both engines in one piece, and steel cross-heads, with all parts easy of access.

In the construction of the dipper, the design of the Atlantic steam shovel has broken away from all precedence in conventionality, but at the same time retaining the points that experience has shown to be correct. The double hoisting-rope is attached directly to the back of the dipper in such a way that the lines of force meet in a point situated in the plane of the resistance. There are several important advantages to be gained by this construction, namely; (1) The bending moment on the dipper arm is eliminated; (2) The full mount of the bucket is free for large boulders, etc.; (3) The dipper is stronger, lighter, and has fewer parts; (4) The dipper can be lifted to a much greater height and reach in proportion to the length of the boom.

The entire back of the dipper is in one piece of cast-

steel with lugs formed upon it to receive the dipper arem, hinges for the doors, etc. The lip and teeth of the dipper are exceptionally strong and are attached so as to be easily renewable.

Independent thrusting engines are employed to feed the dipper to its work. By their use the engineer has absolute control of the dipper and can cause it to fill every time while in a proper bank. Independent reversible engines are employed for swinging, a duplicate of those on the boom for thrusting, and are double-geared to a drum. The drum carries double steel wire-ropes on each side, which are connected to the turntable.

The steam-shovel is mounted upon two steel trucks of diamond-shaped pattern, specially designed for the purpose, and having a larger excess of strength over the requirements. The rear truck is fitted with hand-brakes.

In Fig. 39, below, is shown the Atlantic steam shovel at work in blasted rock. The shovel's ability to raise large boulders will be noted from this illustration.

Fig. 39.

Fig. 40.

Fig. 41.

In Fig. 40, above, is shown the same shovel at work loading the blasted rock ready for shipment.

Fig. 41 shows a stationary shovel excavating beside a railroad track. The construction of this shovel is identical with the one described except that it is mounted directly upon the ground instead of upon a car.

Fig. 42.

The shovel shown is at work reducing grades preparatory to laying track. The construction of the cab of the shovel is well illustrated here.

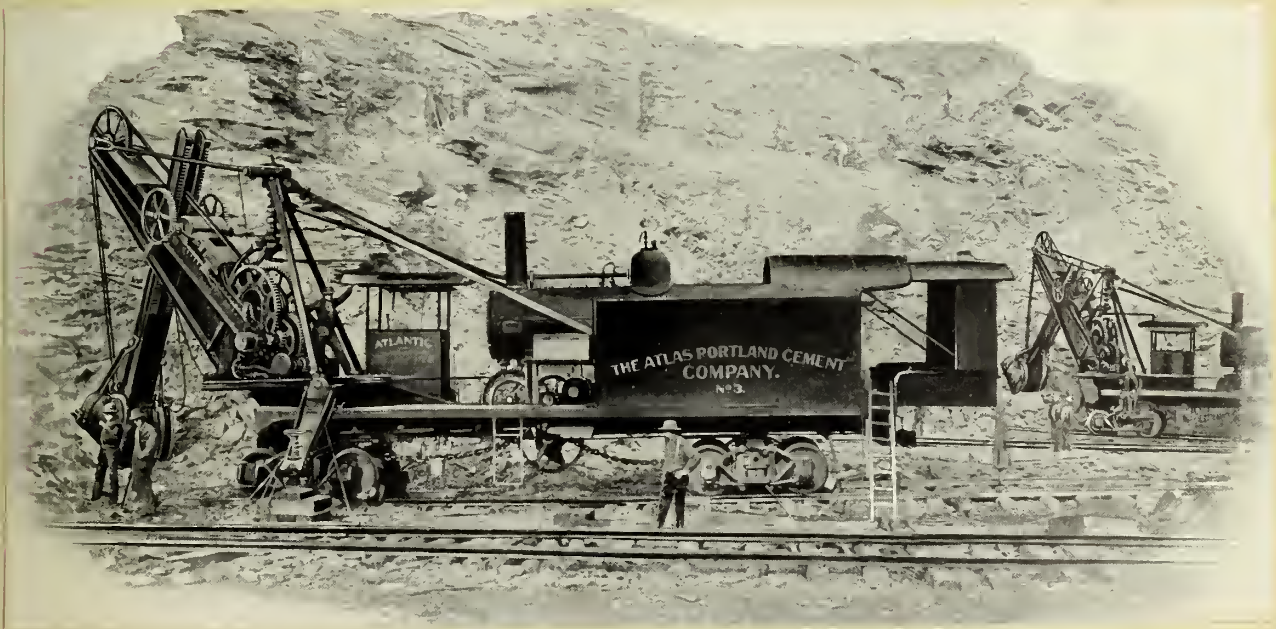


Fig. 43.

In the above illustration the shovel shown is excavating rock in a cement quarry.

Fig. 44.

The machine is here shown loaded upon a car and ready for transportation.

Fig. 45.

Fig. 45 shows the construction of the Bucyrus shovel, manufactured by the Bucyrus Co., of South Milwaukee, Wis.

In Fig. 46, shown below, the Bucyrus shovel which is capable of revolving through 270 degrees is shown at work upon railroad construction.

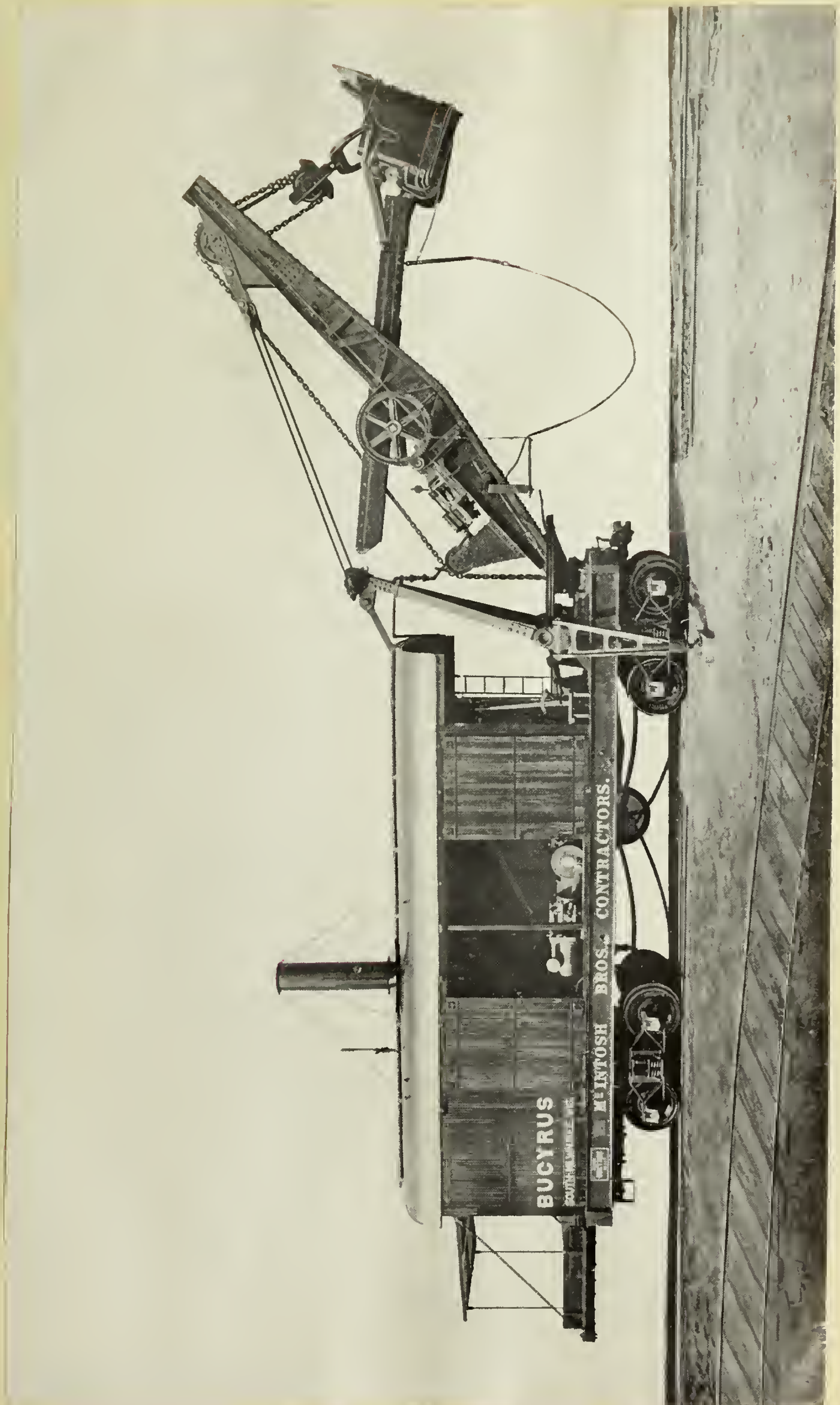


Fig. 46.

Fig. 47.

Fig. 48.

Fig. 47 and Fig. 48 are views of the Marion shovel, manufactured by the Marion Steam Shovel Co., of Marion, Ohio.

Fig. 49.

Fig. 50.

The above illustrations show the Vulcan steam shovel at work on railroad excavation.

Fig. 51.

Fig. 52.

Fig. 51 is a view of a 1 1/4 cubic yard Vulcan shovel excavating earth on new road construction.

Fig. 52 shows a Vulcan tunnel shovel specially equipped with a short crane for excavating in railroad tunnels.

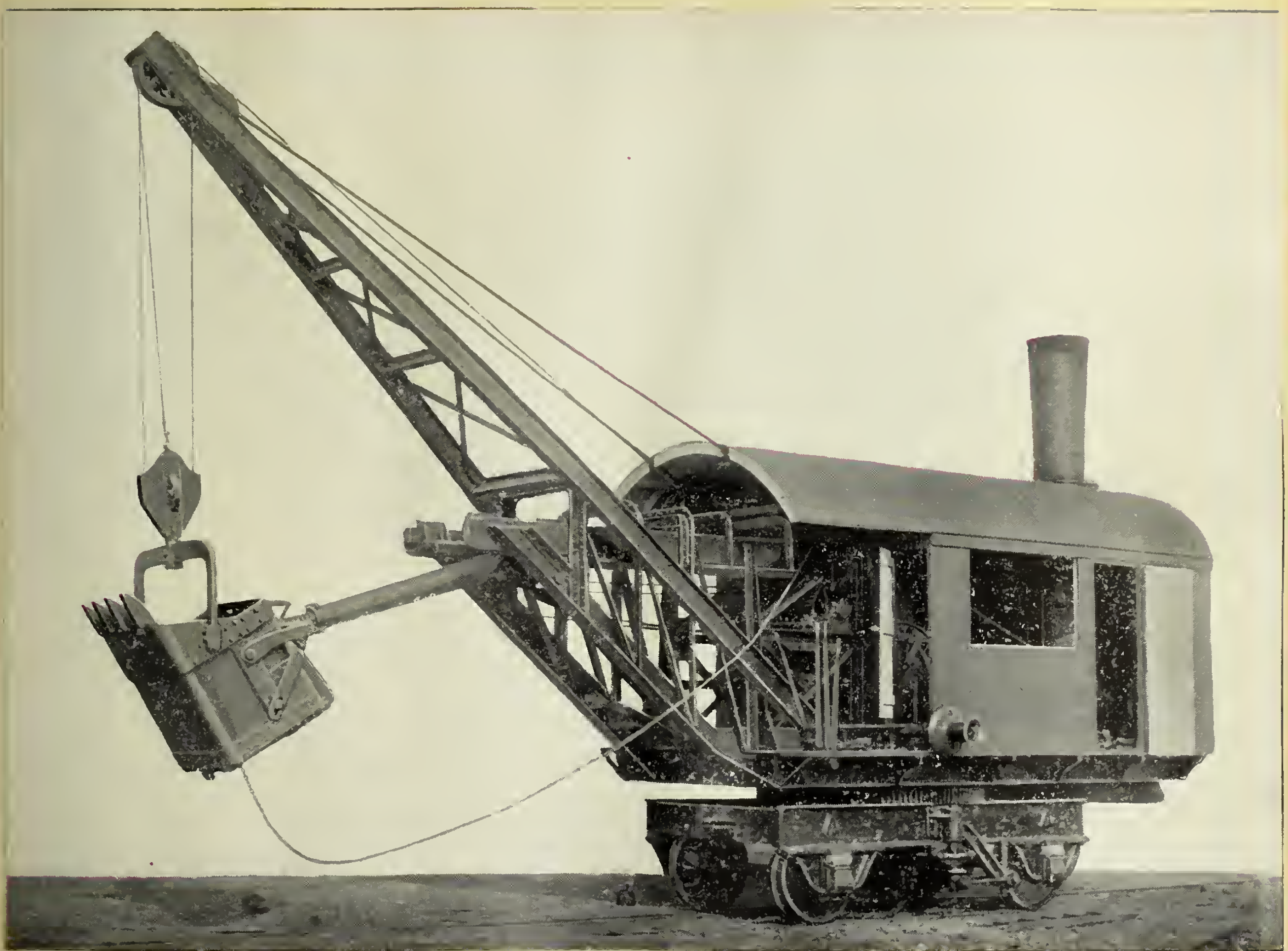


Fig. 53.

A Thew full-swing shovel capable of revolving through an angle of 180 degrees.

Fig. 54.

A special type of the Thew shovel designed for loading coke at the ovens.

Although the steam shovel is employed mostly on railway work, it is not exclusively a railway machine. It is already largely used on other work, and its use in this direction is rapidly extending, especially on the increasing number of extensive public works in the vicinity of large cities. It is employed in excavating canals, harbor and dock-work, stripping coal fields, stone quarries, etc., and the general manner of using the steam shovel on these works is essentially the same as for railway work. It varies, however, only in details, depending upon the means of disposing of the loaded materials, which largely is by wagons, carts, or dump cars.

Powder and dynamite are frequently used to a good advantage to break up and shatter the harder materials before excavating. When thus broken up, about twice the usual amount of these materials can be loaded in a day. The use of dynamite is confined mostly to boulders, ledges of rock, and stumps of trees, while powder is generally used for hardpan, shale, slate, cemented gravel, and hard clays. For the latter materials dynamite is usually too powerful, because instead of merely loosening and lifting them, as desired, it shatters shale and slate into fragments.

Assuming good management and a competent crew, the daily output of a steam shovel depends mostly upon the nature of the material excavated; it is also somewhat dependent upon the height and width of the face of the cutting, and largely upon the facilities for disposing of the loaded material, and keeping the machine constantly at work by an ample supply of empty cars and wagons. Although these varying conditions differ on each

piece of work, the probable output of a machine for a given excavation can be closely estimated by good judgment based on previous experience with similar work.

TRENCH MACHINES.

There are numerous machines that may be employed in digging trenches, but it is that type of machine which is especially designed for trench work that is to be described at the present time. Trench excavation consists more essentially of digging trenches for sewer, gas, and water mains; farm tile drains, open ditches and canals for land drainage and irrigation. The machines employed in this work are of three distinct classes; (1) those that merely excavate the earth, or excavating machines; (2) those that replace the earth, or backfilling machines; and (3) those that are a combination of these, or excavating and backfilling machines.

(1) Excavating Trench Machines.

The development of trench excavating machinery may be said to be still in its infancy. Although many machines have been placed upon the market, only a very few have passed what might be termed the experimental stage. It is only these few, in fact, that have by experience proven their worth, that will be treated in this work.

The trench excavating machines that are, at the present time, in use, are of varied design, but all contain the same essential parts, namely: means of power and its application, cutter, and earth conveyor. All trench excavators may be classified in to the following types: (a) chain excavators, (b) wheel excavators, and (c) miscellaneous.

(a) Chain Excavators:

The distinguishing feature of the chain type of excavator is that it works on the principle of the ladder dredge, but excavates on the inside up-stroke, where the chain lies abreast

of the work. An advantage of this type is that it can be more conveniently and economically repaired in case of damage. The machine tends to give, to a certain extent, in case it encounters large boulders. This type of machine is capable of digging a much wider and deeper trench than any other type. But, notwithstanding these advantages, several serious objections are raised to the machine by enemies of this type. They claim that the machine is incapable of cutting a smooth, clean trench, and that it cannot cut accurately to grade. Also, it is constantly breaking down and in need of repair, because the dirt and grit get into the joints of the chain and quickly cut them out. The time lost in repairing this damage is more objectionable than the cost of repairs. It is this last defect, it is claimed, that will in time finally eliminate the use of the chain type of trench excavator. Among the chief machines of this type are the Chicago Sewer Excavator, the Parsons Trench Excavator, and the Stephens Excavating, Elevating and Delivering Machine.

The Chicago Sewer Excavator, together with the Austin Trench Machine, is manufactured by the Municipal Engineering and Contracting Company, of Chicago, Ill. The machine is entirely self-contained and consists essentially of the boiler, engine, cutter, and conveyor. The general construction of the machine is shown in Fig. 55.

The boiler is either of the horizontal or vertical type, and of a size depending upon the size of the machine. The engine is a simple horizontal one and of varied horsepower. Some machines are equipped with a gasoline engine.

The cutter consists of a ladder frame at the rear end of the machine upon which travel endless chains, carrying a series

of cutters and scrapers. The ladder frame is held down to its work by rack bars and pinions. The cutter is situated well in the rear of the machine, so as to be sufficiently distant from the large hind wheels of the machine and thereby produce a minimum of lateral earth pressure. Fig. 56, which shows the cutters very well, is an illustration in which the digging boom is let down to its maximum depth. The machine is operated by a two-cylinder, 7 x 9 inch gasoline engine.

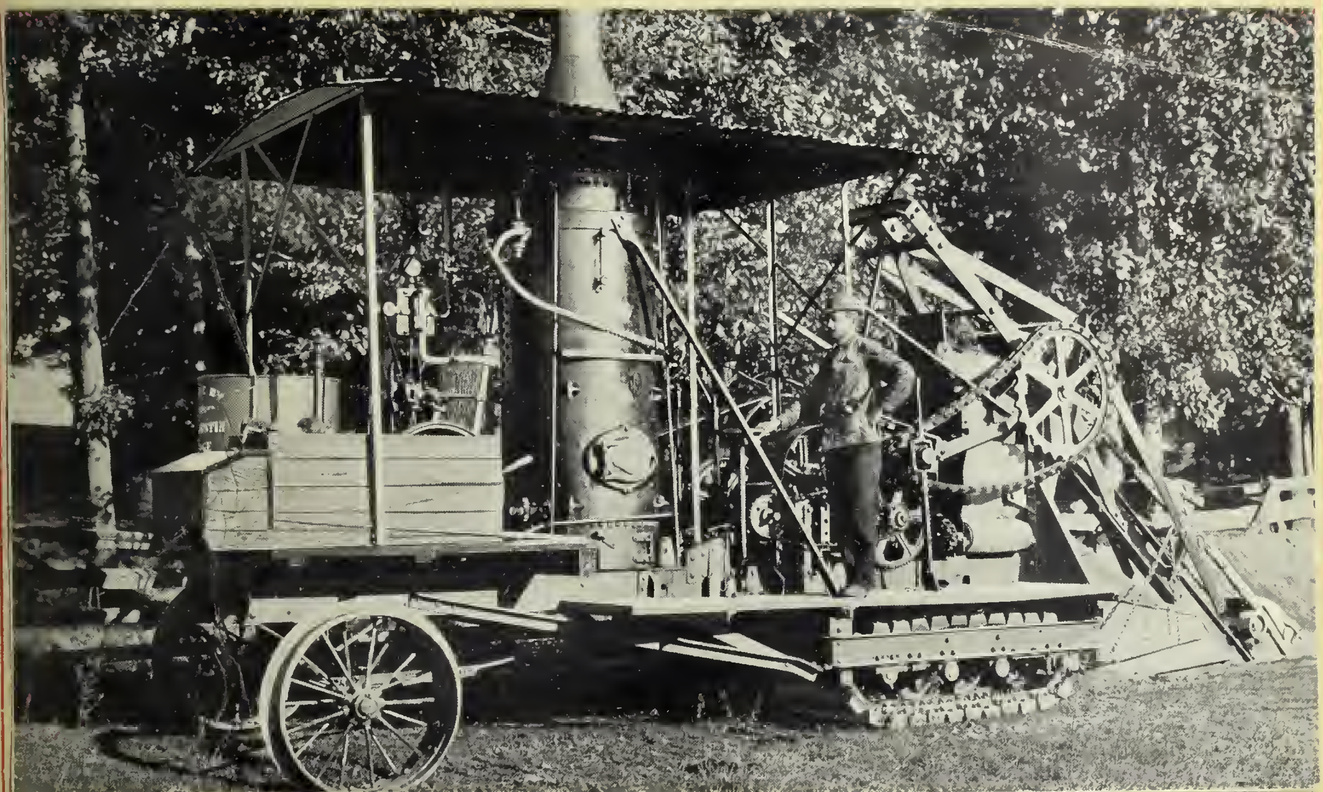


Fig. 55.

The conveyor consists of a transverse belt, upon which the buckets discharge, and which conveys the earth to one side of the trench, thus leaving it ready for the backfilling. It can be attached to either side of the machine. The material is discharged into wagons which are run alongside of the machine, if it is desired to remove the earth. An equipment which has been tried, but which has not as yet proven entirely satisfactory, is a sec-

ond belt conveyor attached to the rear of the machine, upon which the excavated material is discharged and conveyed back and into the completed trench. A serious objection to this second conveyor is the large amount of space it takes up and its awkwardness in transportation. It is operated by a separate engine which receives its steam from the machine boiler. An admirable feature of the conveying cutter aprons is that they are hinged and as they pass over the top sprocket wheels, they are given a slight jerk which deposits the earth upon the conveyor belt and thus prevents it from sticking to the cutters.

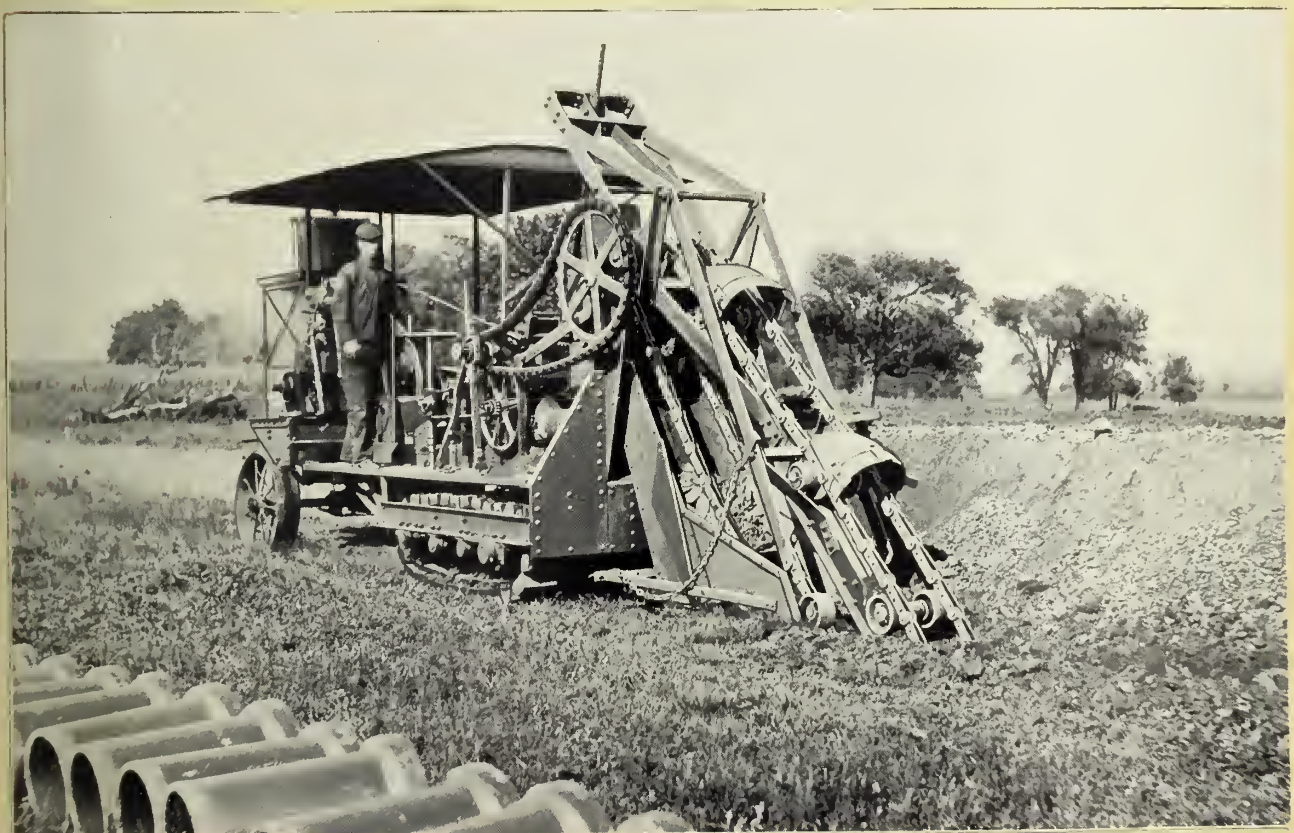


Fig. 56.

The traction of the machine is usually of the wheel type, but in case the machine is intended for work in soft ground, it is equipped with a roller platform traction. With this equip-

ment it has large front wheels which have extremely wide surface bearings. The rear wheels consist of endless chains carrying transverse planks, the chains running over two sprocket wheels one of which is driven from the engine. These wheels are very flexible and will pass over any ordinary obstruction. The use of the roller platform traction does away entirely with the bother of planking the route of the machine. The roller platform traction is shown to good advantage in Fig. 57.

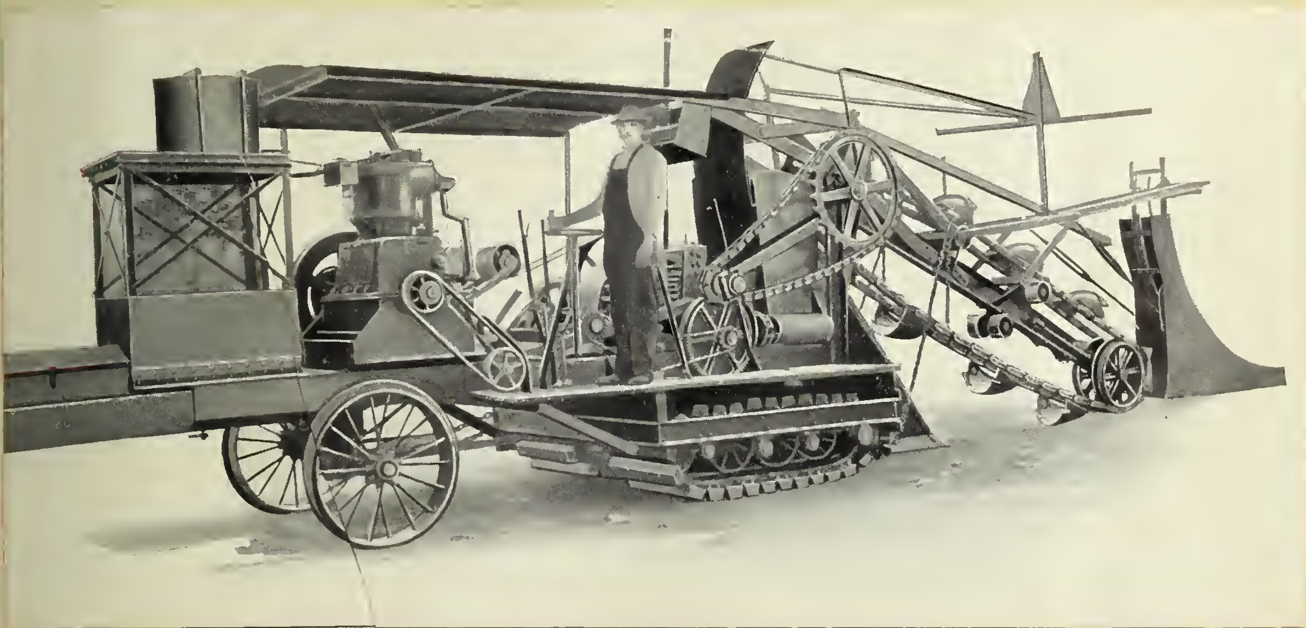


Fig. 57.

The machine is manufactured in various sizes, ranging up to and including one that is capable of excavating a trench 20 feet deep by 60 inches wide. The capacity of the larger type is rated at 500 cubic yards per day.

The machine will work in any kind of soil that can be either plowed or picked, but cannot work in ground containing either quicksand, many boulders, large roots, or numerous service pipes. Although it can excavate boulders the size of a peck measure, if it strikes some that it is impossible to dislodge,

the carrier can be automatically raised out of the ditch, and the boulder moved out of the way. Work has been carried on satisfactorily in tearing up light asphalt and macadam paving. The buckets themselves are self-cleaning, so there is never any clogging or choking of the machine because of sticky soil.

Tough clay is the easiest material to excavate because the cutters work with so much ease and regularity, never encountering any obstacles. Although the machine can operate in soft, wet ground, it does not do so satisfactorily. Straw is sometimes thrown into the trench and mixed with the muck, thus making a more solid mass, thereby enabling the machine to excavate it. At Marsfield, Wis., it cut through a mile of logging road where the logs were buried in the ground from two to ten feet and were from six to thirty inches in diameter. It is not advisable, however, to use the machine for such heavy work. In St. Louis two to four-inch service pipes have even been cut.

In excavating for tile drains in a wet country where the ground caves in as fast as it is dug, the automatic tile chute attachment, shown in Fig. 57 and a clearer view in Fig. 58, proves invaluable. The makers claim as an absolute fact that tile can be laid to grade.

The speed of the machine is generally about one foot per minute, but much depends upon the soil and obstructions encountered. A notable feature of the machine is that it can work in as narrow a space as a twelve-foot alley and yet do its work satisfactorily. It is in alley excavation that the backfiller previously mentioned can be used to advantage.

The machine was designed to do away, to a great extent, with

the need of lateral bracing in the open ditch, but it has not, in a great many cases, succeeded in cutting a sufficiently substantial trench.

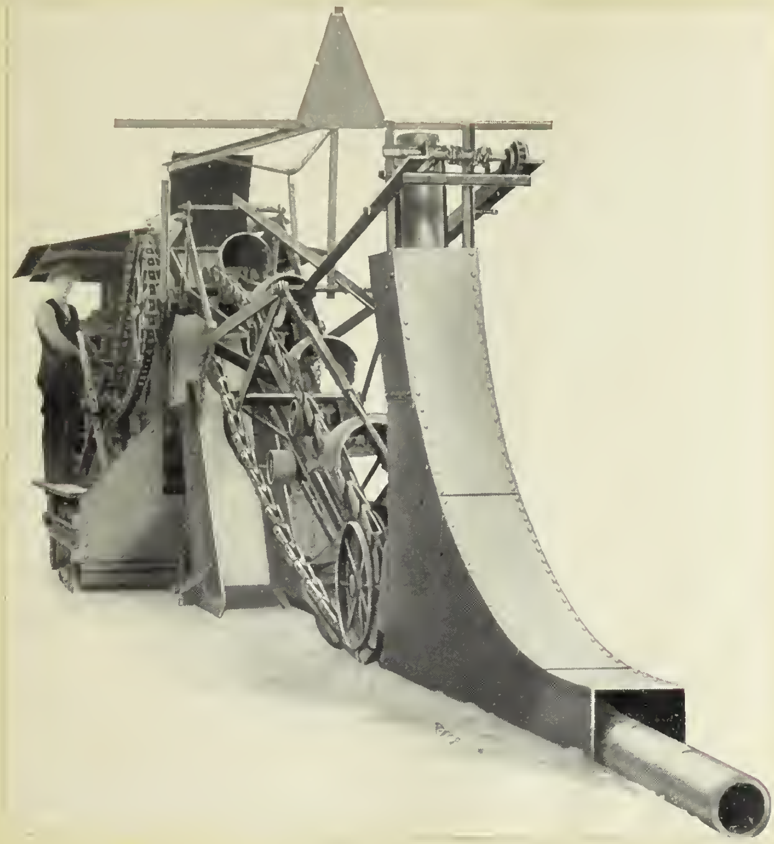


Fig. 58.

The construction of the excavator is not at all complicated, as can be seen from the foregoing cuts.

The Parsons Trench Excavator is manufactured by the G. W. Parsons Co., of Newton, Iowa. It is of very similar design to the Chicago Sewer Excavator and differs materially only in that the ladder frame and conveyor belt are carried by a separate two-wheeled truck which is coupled behind the main portion, and which carries the engine and driving machinery. The construction of the machine is clearly shown in Fig. 59. The machine is entirely of steel construction, no wood being used except for the coal and

Fig. 59

tool boxes. It is either gasoline or steam driven. A noteworthy feature is that nearly the entire weight of the machine rests on the two large propelling wheels, which are at all times more than ten feet in advance of the face of the ditch, and therefore the weight and vibration of the machine can in no way effect the stability of the walls of the newly excavated trench. The ditch can be braced within a very few feet of the machine, as shown in Fig. 60, thus making excavation in wet ground possible to a certain extent. Fig. 60 is a view of a trench 78 inches wide by 2 feet deep that was dug in 1807 at Des Moines, Iowa.

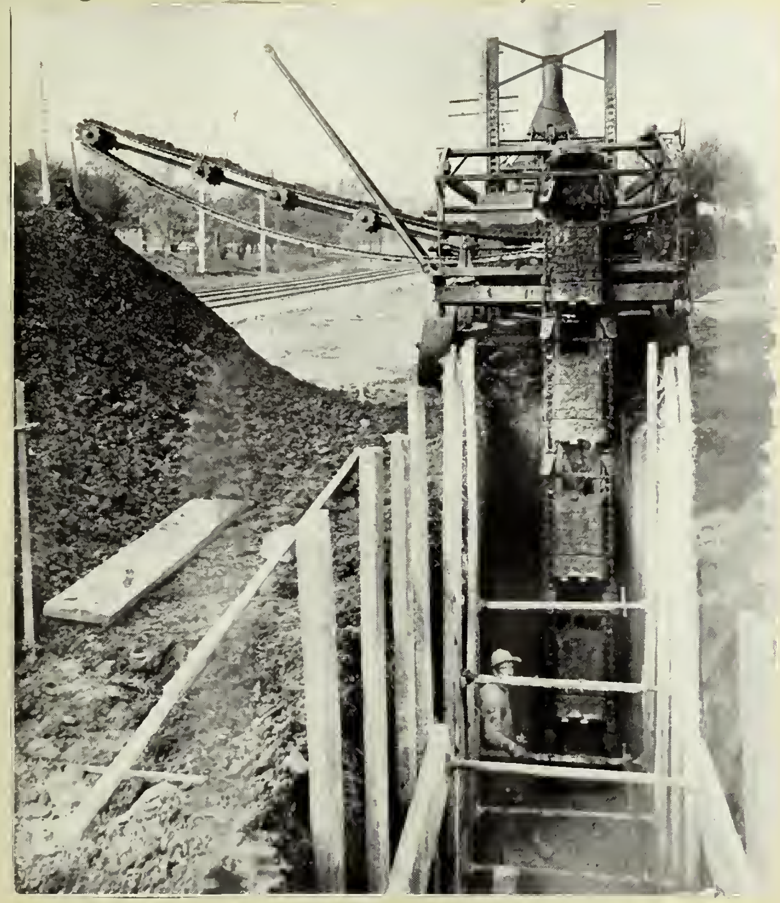


Fig. 60.

The excavator can be operated in narrow streets or alleys with equal dispatch and efficiency, and where there are countless gas, water, and sewer pipes,and with other obstructions

virtually hidden from view, the same economy of operation prevails. In Fig. 61 is shown the digger raised to enable it to pass over service pipes, crossings, etc. The machine, overall, is but ten feet in width. The carrier is constructed entirely of steel, and is extensible, so that excavated material can be placed at any desired distance from the walls of the trench and on either side. Fig. 62 shows an illustration of the machine working in a narrow alley and depositing material on both sides of the ditch.

Fig. 61.

Fig. 62.

Fig. 63.

The excavator is self-propelling, moving of its own power, at the desired speed when digging, and from two to three miles per hour when travelling from place to place. Fig. 63 shows the machine on the car ready for shipment. It is very easily set up ready for work, taking but a day and a half for the operator and his helper to do this.

The Stephens Excavating, Elevating, and Delivering Machine is the invention of Mr. J. W. Stephens, of New Orleans, La. The machine is a comparatively new one, the patent for which having been received only in 1804. It has, up to the present time, been used only around the vicinity of New Orleans.

In the method of operating, this machine differs from all others of its kind in that not attempt is made to cut the full width of the trench at one stroke. Instead, three slices are cut by the scoop, in excavating a trench say 6 or 7 feet wide.

In order to do this, the upper or machine platform is movable, transversely, on the lower, or truck platform, which rides on a track.

The machine consists, essentially, of an endless chain elevator, symbolic of the type, which delivers the earth upon a transverse belt conveyor, that, in turn, delivers the earth into cars or wagons, or piles it alongside of the trench. At the lower end of the bucket elevator is a scoop provided with teeth and a cable leading to the hoist. As this scoop is pulled up alongside the face of the trench, it cuts off a slice of earth from 6 inches to 9 inches thick and about 2 feet wide. The loosened earth is forced to the back part of the scoop, exactly as in loading a drag or wheel scraper, and there it is caught by the buckets of the elevator. This is an excellent solution to the problem of loading the elevator buckets, because a direct and powerful pull can be applied to the scoop, so as to cut through tough soil, and at the same time neither the elevator nor its framework is put under strain.

The upper end of the bucket elevator is supported by pivoted connections to a controlling boom and this boom is in turn supported by a bale and wire rope which passes over a sheave at the top of the crane boom and down to the hoisting drum.

In starting to excavate a trench with this machine, the first operation is to raise the controlling boom to such a height as to allow the scoop to swing back as far as possible beyond the vertical. It is then lowered until the teeth of the scoop bite the earth, whereupon the scoop is drawn forward and upward by the cable leading to the hoisting engine. By slowly hauling the

machine forward on its track and slightly lowering the controlling boom at each swing-out, the desired depth of the cut is obtained. Thereafter, straight-ahead cutting is done by raising and lowering the scoop. It should be noted that the machine is always supported on solid ground in advance of the trench. Furthermore, it cuts a trench with perfectly smooth sides, thus requiring no hand-trimming. In a trench 6 1/2 x 12, it is stated that it required less than two minutes to take off a slice from 6 to 9 inches thick.

The Hovland Machine was designed especially for ditching and tiling in soft, wet ground. In view of this fact, it was built in two separate parts, one of which carries the engine and driving machine, and the other, the excavator and conveyor. The power is transmitted entirely by driving chains. Each part of the machine is mounted upon apron tractions. There may also be attached to this machine, as to the Chicago Sewer Excavator, an automatic tile chute, thus making possible the laying of tile in treacherous soil.

The Helm Machine is one in which the chain vertically upon a telescopic frame. The ascending side of the chain is diverted by sheaves to a horizontal run over the end of the conveyor, and then it returns to the top of the vertical frame.

(b) Wheel Excavators:

The wheel type of trench excavator is fast becoming immensely popular with the American contractor, a great deal more so that the chain type. The cause of this is that with the wheel type, breakdowns and accidents are few, and thereby little time is lost in making repairs. It is true, however, that when such do

occur they are for more serious than the ordinary accidents with the chain type. It is, nevertheless, the time element that will eventually decide the superiority of the two types, because with trench excavation, as with other work, time is money. A serious drawback of the wheel type is that the largest trench that it is possible to excavate, is one 4 1/2 feet wide by 12 feet deep. When digging within its bounds, however, the defects of the wheel type are extremely few, since it is rapid, clean-cutting, stable, rigid in its motion, economic of operation, and continuous in its work. Prominent among this type of trench machinery are the Buckeye Traction Digger and the American Ditcher.

The Buckeye Traction Digger, patented in 1894 by Mr. J. B. Hill, is manufactured by the Buckeye Traction Ditcher Co., of Findlay, Ohio. This machine is perhaps the best known and most widely used of any of the wheel type. The general construction of it is clearly shown in Fig. 64

Fig. 64.

The distinctive feature of this machine is the large wheel at the rear, upon whose periphery revolve the excavating buckets. The wheel is of the open type, having no spokes or axle, but revolves upon a fixed frame, carrying at the quarter points anti-friction rollers bearing against the inner face of the rim. It is supported between two I-beams that project from the rear of the trucks. These I-beams can be instantly raised or lowered by the operator so that the bottom of the wheel can be placed at the exact depth desired. It will be noted that the wheel is at the extreme rear of the machine, and as the machine advances the completed trench is left behind, thus allowing none of the weight of the machine to come upon the walls of the ditch, causing lateral earth pressure and tending to cave in the trench.

The force of the wheel is applied directly, because the driving sprocket is directly over the point where the earth is excavated. Here the principal reason for the open type wheel comes to light, because the weight of the wheel is far less than would be required if the wheel were driven from an axle. It will be seen that as the I-beams to which the wheel is attached are above the center of the wheel, excavation to a greater depth than the extent of the radius is possible, thus allowing a comparatively small wheel to dig a great depth of trench.

The buckets are peculiar in design, having no backs, but sliding around on the steel perimeter which holds the rims of the wheel the proper distance apart. Semi-circular hoods form the tops of the buckets. On a small machine used for excavating trenches not more than 5 1/2 feet deep, there are 36 cutters and a larger number on the sizes cutting to a greater depth. There are two series of cutters attached to the buckets, those that

excavate the center, and those that trim the sides of the trench. The center cutters are simply the prolonged and hardened edges of the buckets, while the side trimmers are flaring teeth, forged from high-carbon steel, attached to each end of the center cutters and projecting in advance of them. Because of these side cutters it is impossible for the excavating buckets to stick or become bound in the trench. Moreover, they scrape all the dirt toward the center of the ditch, where the buckets must pick it up and so a perfectly clean trench is left behind. A noteworthy feature of the buckets is that they pulverize the earth, thus making the backfilling a great deal easier. Fig. 65 shows a view of a trench left behind by a 20 inch by 7 1/2 foot machine. The straight, vertical sides of the trench will be noted in this illustration. At the top of the wheel the excavated earth is dropped upon a lateral belt conveyor and carried to one side of the trench where it piles up; or,if desired, the earth can be delivered into wagons which are run alongside of the trench.

Fig. 65.

Any ground that can be loosened with a pick can be excavated with this machine. It can excavate hardpan, shale, frozen earth, light asphalt, or macadam pavement, and even material approaching ledge rock. It can cut through solid logs buried in the ground, and it has been known to cut through service pipes. In fact, the machine can excavate almost anything but solid rock. When excavating in marsh or swamp land, the machine is equipped with an apron traction.

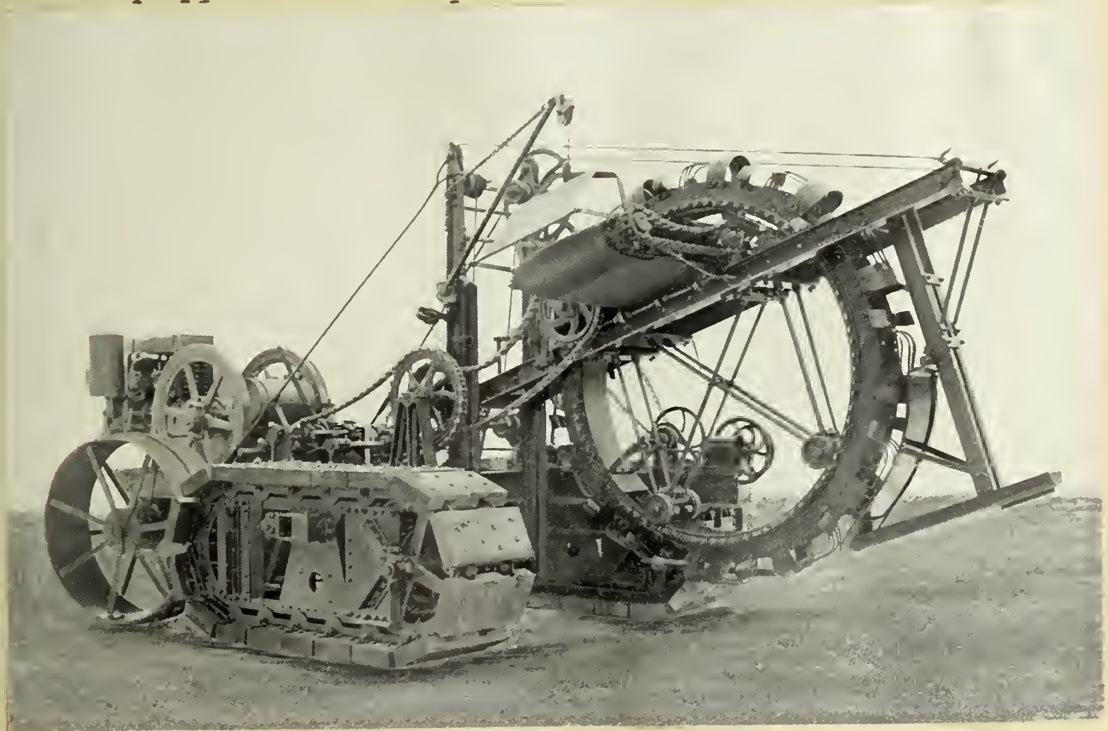


Fig. 66.

The construction of the apron traction is shown in Fig. 66, and, as the design closely resembles those used with the Chicago Sewer Excavator, it will not be described here. The chief difference, however, being that the Buckeye apron traction is much larger and composed of heavier material. The makers claim that a machine so equipped can travel any place where a team and wagon can go. Without this apron traction it would be impossible for the machine to excavate in soft, muddy ground.

When excavating in wet, sticky soil, open-back or skeleton buckets are provided.

Some machines, usually the smaller ones, are provided with automatic cleaners when working in sticky soil. There are two cleaners, an upper and a lower one. The upper cleaner works so that the action of the excavating wheel itself forces a spade into each bucket in turn, and as the cleaner revolves, the spade is forced downward, thereby discharging the accumulated earth onto the elevator. As for the lower cleaner, when a bucket gets into the right position, the cleaner,attached to a coiled extension spring, is forced through the sticky mud until it strikes the back of the bucket, and then the action of the bucket in going down causes its back to be scraped and relieved of the earth, and the cleaner goes back to its original position, ready for the next bucket.

When the machine is in operation, range poles are placed in the ground ahead of the machine, and the operator can, by sighting along these, cut a perfectly straight trench. He can also cut a trench curved either to the right or left. These range poles are also fitted with sliding targets, so that the machine can cut exactly to grade.

The machine is self-propelling and can advance at any special speed desired. When traveling from place to place,it is capable of making from two to three miles per hour. It is entirely chain driven. The machine is manufactured in different sizes varying from one that cuts a trench 11 1/2 inches wide by 4 1/2 feet deep to one that cuts a trench 54 inches wide by 12 feet deep. The cost of the machine varies from $1,200 to $10,000.

It can be either run by gasoline or steam power, the former usually costing slightly more. The cost of operation is about $16 per day when the capacity is about 1,000 cu. yds.

The American Ditcher is manufactured by the American Ditcher Co., of West Minneapolis, Minn. This machine is of very similar design to the Buckeye, but differs somewhat in regard to details. The construction is clearly shown in Fig. 67. The excavating wheel is spoked and is suspended from the axle of the propelling wheels by a cast-steel yoke. It is double rimmed, and

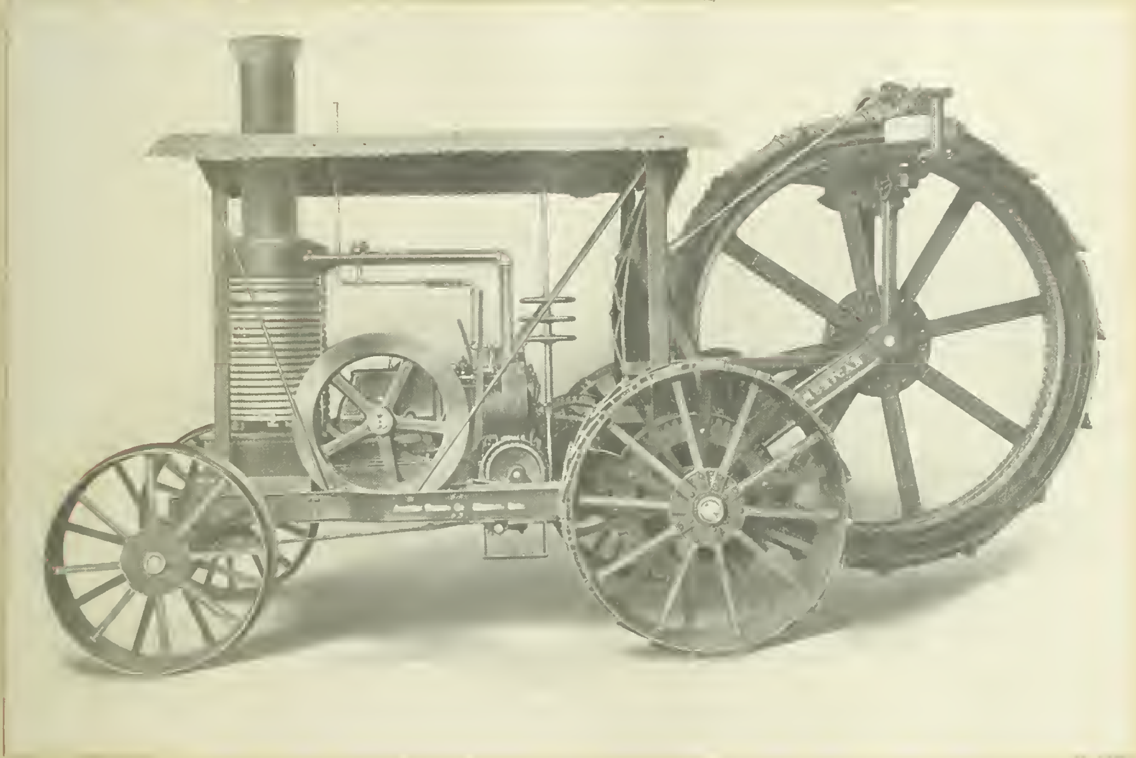


Fig. 67.

between these rims is a 6-inch I-beam continuous around the circumference. In the outer rim are 16 6-inch openings extending completely across it, and to the edges of which are attached the hard, crucible steel cutting knives. A very clear view of these cutting knives can be seen in Fig. 68. As the wheel revolves, these knives shave off a slice of earth from one-half inch to

Fig. 68.

one inch in thickness, which is forced through the six-inch openings and into the continuous space between the rims. The earth is forced to the top where steel plows, which just fit the continuous space between the rims, deflect the dirt and cause it to drop upon two conveyor tables. These conveyor tables are revolving steel disks, at the outer edge of which are stationary plows or scrapers which force the dirt from the tables. The tables are of large enough diameter, so that when the dirt drops from the edge,it is deposited at a convenient distance from the excavated trench. They are kept level automatically, and the earth is thrown equally on each side of the trench. Fig. 69 shows the machine digging

Fig. 69.

in sticky soil and depositing it on both sides of the trench.

The machine can be run either by gasoline or steam power and can easily be operated by one man. A chief asset of this make is its compactness. It weighs about 700 pounds per horse power. The tractor is so complete and flexible that if the digging wheel were taken from the machine, a perfect traction engine would be left. It can be shipped from place to place on a flat-car, without being taken apart. When traveling by its own power it can run at the rate of three miles per hour. The makers claim that it can excavate 80 cu. yds. per hour from a trench 6 feet by 2 feet, or will travel, when so doing, at the rate of three feet per minute. This is, however, exaggerated, because no machine can possibly do this except in the very best of tough, hard clay.

The machine, although entirely satisfactory when working

within its limit, has not a large enough scope of power. It is small, compact, and light, but is incapable of doin g heavy work. For light work, as shallow trenches in good soil, it cannot be excelled because of its great speed.

Another important machine of the wheel type is the Dalton machine, in which the arms or spokes of the excavating wheel are pivoted to the hub. As each arm rises from the trench, it is released from the rim and swings outward, dumping the contents of its bucket on one side of the trench. It then swings back against the wheel and is locked to the rim before again descending into the trench.

In the Miller machine, there are six arms set alternately on opposite sides of the rim. Each rim carries an excavating bucket, and as the arm comes to a horizontal position, a hinged hopper falls into place beneath the bucket and the bottom of the bucket is released, whereupon the contents fall through the hopper upon a lateral belt conveyor.

(c) Miscellaneous Excavators:

Prominent among the miscellaneous ditch excavators is the Austin Drainage Excavator, manufactured by the Austin Drainage Excavator Co., of Chicago, Ill. This machine is shown in Fig. 70. It was especially designed to overcome the difficulty resulting in open ditches and drainage canals, caused by the caving-in and sliding of the banks, thus making a rough and irregular ditch and obstructing the flow of the water. It is essential that the banks be left smooth and even, so as to avoid a subsequent trimming, which adds greatly to the cost. With an aim in view to overcome this difficulty the machine was designed to cut the ditch with the proper slope.

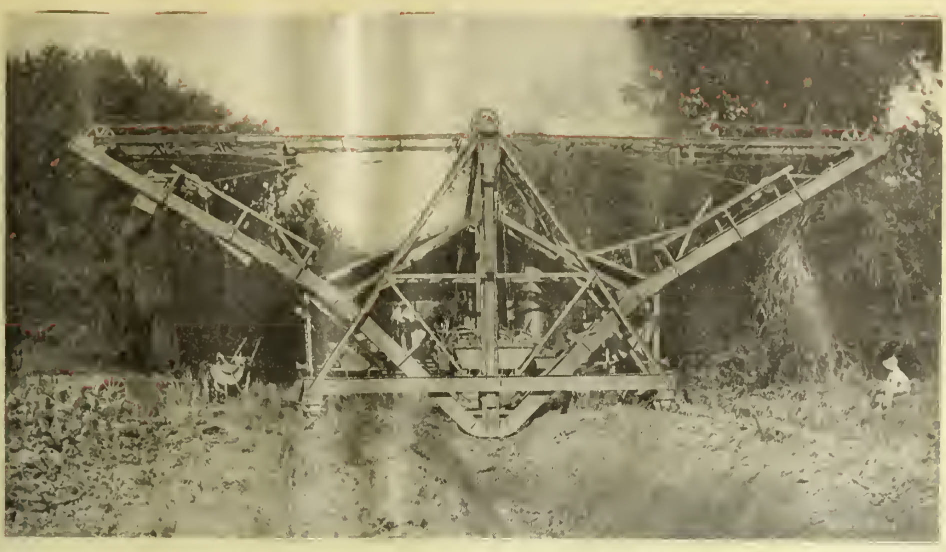


Fig. 70.

The principle of the machine is that of two excavating buckets working transversely across the line of the ditch, traveling upon a template shaped to the desired cross-section, and run out on side booms to dump their contents upon the ground. These excavating buckets, which hold about 1 1/3 cubic yards, shave a thin slice down one side, across the bottom, and up the opposite side. The template carrying the buckets is lowered as the ditch increases in depth, so that the banks and bottom are cut to the required cross-section.

When excavating in soft ground, the machine is capable of excavating to the full depth of the ditch before moving. But in firm, hard ground, it must make a continuous cut of about 1,000 feet for the first setting of the template, and then travel back and forth over this distance until the full depth is completed. The machine can be adjusted to dig any ditch from 30 feet wide at the base and one foot deep, to a ditch 8 feet wide at the base

and 12 feet deep. It is rated to excavate from 50 to 75 cubic yards per hour in good soil. It is equipped with apron tractions on both front and rear wheels. It is self-propelling and can attain a maximum speed, when traveling from one place to another, of one mile per hour. The machine is mounted on wheels which run on a track. All the labor required to operate the machine is an engineer, fireman, and two laborers to take care of the track.

A modification of this machine is shown in Fig. 71. It has an endless chain of buckets, placed transversely to the line of the ditch, which travels over a template. The buckets deposit the earth upon the embankment, and at a sufficient distance from it so as not to impair the strength of the walls. The machine is also mounted on wheels which run on a track. It can be equipped with apron tractions.

Fig. 71.

The Jacobs machine, which is of very recent design, is the invention of Mr. Charles C. Jacobs, president of the Jacobs Steel Excavator Co., of Amboy, Ill. The machine was designed especially, as was the Austin, for excavating drainage ditches and irrigating canals.

The machine is mounted on the frame carried by the wheels, which travel on rails laid on each side of the excavation. Beneath the frame is the steel template, which is shaped to the required cross-section, and which carries the excavating buckets. From each end of the frame there extends an inclined steel boom, at the ends of which the buckets are dumped. The two buckets travel in opposite directions upon the quide frames, and dump automatically. All the operations of the machine are effected by means of a double drum hoisting engine, and, being self-propelling, it requires no anchors or spuds. This style of machine is capable of excavating 800 to 900 cubic yards per day with a consumption of about one ton of coal. The only help necessary is an engineer, fireman, and a man with a team to tend to the laying of the track.

The advantages claimed for this machine are a reduction in power and labor, as compared with a dipper dredge of the same type, and the banks are left in a better condition to prevent slides and to give the full capacity of flow to the channel.

The Bowman Ditcher is a railway ditching machine for widening ditches in small railway cuts preparatory to double-tracking, and for cleaning existing ditches in earth cuts where a smooth, even slope is desired. An objection has always been made to the steam shovel in doing this work, because this work is not of sufficient magnitude to warrant its use. This machine,

however, overcomes this objection, and it does the work more economically than manual labor. It is the invention of Mr. Ben Bowman, of Springfield, Mo., and is built at the Sacremento shops of the Southern Pacific R.R. Co.

The general construction of the machine can be seen from Fig. 72. It consists of the cranes, compressed air equipment, plows, scoops, slopers, and spreaders.

Fig. 72.

There are two cranes on each side of the car, which raise and dump the scoops and assist in guiding the plows and slopers. The car is similar to an ordinary flat-car.

The compressed air for the pneumatic hoists is furnished by the three compressors, which, together with the reservoirs, are situated at the front end of the car. The steam for the compressors is supplied from the boiler of the attendant locomotive.

The plow is shown in operation in Fig. 73, and is hung from the main chain of the hind crane. Its line of action is con-

trolled by the guiding cylinder acting through a steel pole attached to the rear end of the plow-beam. A special plow of extra-heavy construction is used on this work.

Fig. 73.

The material loosened by the plows is collected by the scoops , as shown in Fig. 74. The scoops are situated, two on each side of the car, one to each crane, and each scoop holds four cubic yards. The scoops are so hung that when lifted after having been loaded they tilt backward, thus ensuring the earth safe carriage in transportation.

The sloper, shown in Fig. 72, consists simply of a flat, laminated plate about four feet square, to which is riveted a curved plate, flaring away from it at the rear, to act like the mold board of a plow. The spreader is used in distributing dumped material, so as to give an even surface to fills and cuts alongside the track.

When in operation the ditcher breaks up the ground with the plow, after which the scoops are pulled through and filled.

When filled, they are lifted by the pneumatic cranes and the locomotive tows the ditcher to the dumping place. When necessary, the dumped material is leveled off by the spreader. The ditcher is then returned to the cut and the final slope of the bank is obtained with the sloper.

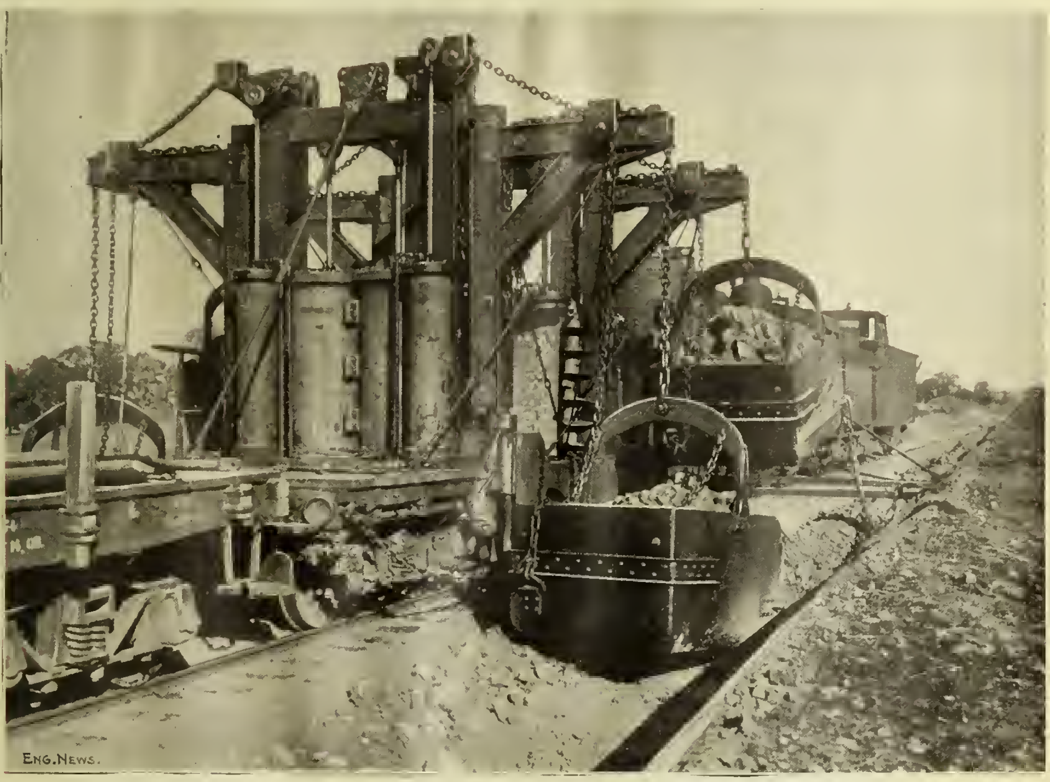


Fig. 74.

The Buckeye Machines are many and varied in design. Their construction can best be shown by numerous cuts. Fig. 75 is an illustration of one of the machines cutting a ditch with vertical sides. In Fig. 76 and Fig. 77 are shown machines that excavate with sloping sides. Fig. 78 and Fig. 79 show ditches that have been excavated with Buckeye machines. Fig. 80 is an illustration of the Buckeye clay digger. It is a new machine, but has proven satisfactory in all cases where it has been used.

Fig. 75.

Fig. 76.

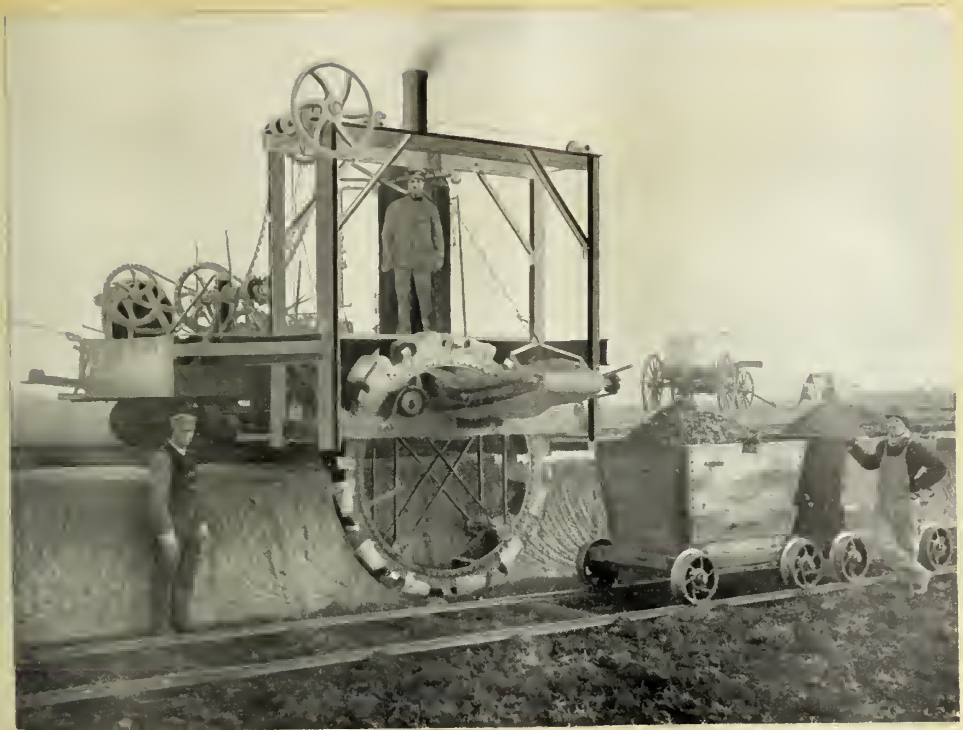


Fig. 77.

Fig. 78.

Fig. 79.

Fig. 80.

The advantages of trench excavating machinery are many. It improves the facility and rapidity of excavation because narrower and deeper trenches can be dug than it is practicable to dig by hand, as staging is entirely dispensed with. The contractor can calculate the cost of the work to a greater degree of accuracy, thereby minimizing the risk of loss due to miscalculation. Backfilling is made much easier, as the ground is pulverized when taken from the machine. The cost of the work is greatly reduced, as the machine takes the place of 50 to 100 men, according to the character of the work. The troubles due to the labor problem are decreased. The work of timekeeping is greatly simplified. There are no strikes, wrangling, and discord among the men. The question of always obtaining low-priced labor does not enter into the consideration when machinery is used.

(2) Conveying Trench Machines.

Long before the time of the present trench excavating machine there existed a so-called trench machine whose sole duty was to replace the earth that had been excavated. The difference in time of the appearance of the two systems of trench work is easily understood, because the problem of backfilling is a far less complex one than that of excavation. There are, however, many different machines for conveying and replacing the excavated material, but the principal ones are of the following types: (a) locomotive cranes, (b) cableways, and (c) trestle systems.

(a) Locomotive Crane:

The locomotive crane is practically identical with the traveling derrick, the former term, however, seems prevalent at the present time. The locomotive crane is an ordinary crane mounted upon a car and possessing the motions of self-propulsion, hoisting,

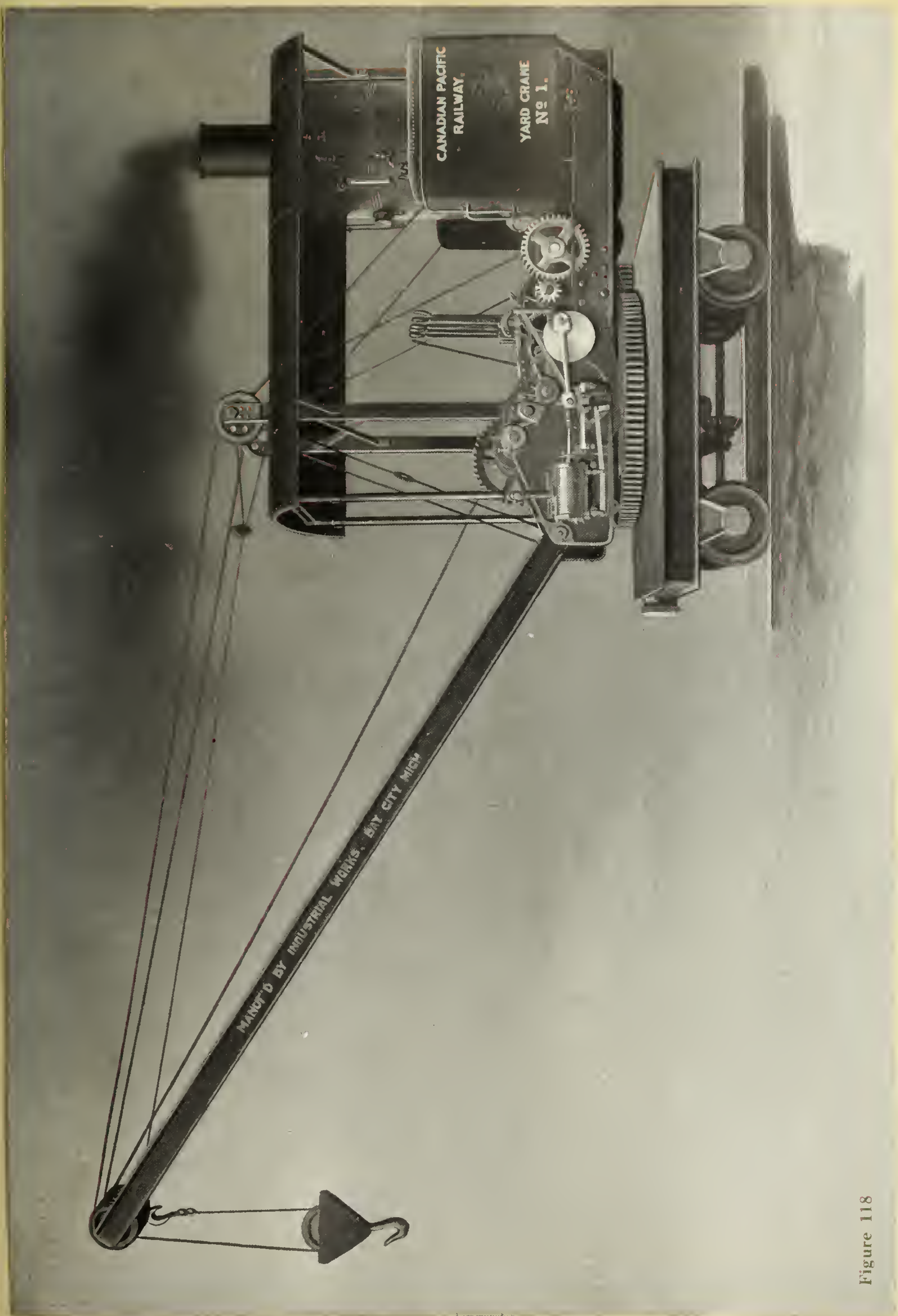

CANADIAN PACIFIC
RAILWAY.
YARD CRANE
Nº 1.
MANUF'D BY INDUSTRIAL WORKS, BAY CITY MICH
Figure 118

Fig. 81.

and pivoting. The design is shown in Fig. 81, and in general it consists of the car upon which are mounted machinery, frames, engine, boiler, and various appliances for the proper operations of hoisting the load and conveying it to any position within the radius of the crane and then moving forward by means of its own power.

The first form of a crane that was used in trench work consisted of a three-legged frame, set astride the ditch, in the apex of which was fastened a pulley around which ran the hoisting ropes. This apparatus was capable only of hoisting the excavated material from the trench, but was incapable of conveying it any distance. It was very inconvenient, having to be moved frequently, and was, if any, scarcely more economical than staging. It is used at the present time only where the work does not necessitate frequent moves.

There are numerous makes of locomotive cranes and almost every firm that manufacutes contractors' machinery builds some kind of traveling derrick. While not a typical trench machine, nearly every locomotive crane can be adapted to trench work. When in operation, the crane is run upon a track which may be either astride or to one side of the trench. The buckets, which are attached to the crane, descend into the ditch, and when filled, are raised, and the crane is moved forward upon its track to a completed portion of the trench, where the material is to be dumped. Another excellent method, which is used somewhat, is to have two cranes separated from 50 feet to 75 feet from each other and then have one crane pass a filled bucket to the second crane, which dumps it.

Although the locomotive crane is economically efficient, it is not adapted to all kinds of trench work. It cannot be used to advantage where there is considerable distance under excavation at one time. It is not adapted for narrow trenches, is not at all suited for city work where the streets are congested, nor is it, in fact, ever resorted to where the use of a typical trench machine would be at all practicable.

(b) Cableways:

Cableways, like the locomotive cranes, are not distinctively trench machines. As trench machines, they have only been used since about 1890, when they were tried in New Jersey merely as an experiment. They proved very efficient and have since been used upon important work. There are a few cableways that are built especially for trench work, and perhaps the leading one of these is the Carson-Lidgerwood Cableway, manufactured by the Carson Trench Machine Co., of Boston, Mass.

The Carson-Lidgerwood Cableway consists essentially of either one or two steel cables suspended between two or four vertical trestles which are securely anchored at each end. Upon these cables travel one or two buckets, having a carrying capacity of about two tons of earth or stone, and which are carried backward and forward by an endless rope attached to a special drum of the engine. The double cable system is shown in Fig.82, and the single cableway is shown in the various other illustrations. When in operation, the buckets which have been filled in the trench are hoisted by a separate steel cable, carried back and dumped into a completed portion of thetrench. The general operation is shown in Figs. 83 and 84.

Fig. 82.

Fig. 83.

Fig. 84.

The operating engine is mounted upon a movable car which is placed at the head of the excavation, behind the trestle, where the working of the engine cannot shake the banks. Beside furnishing the power for the operation of the buckets, it is large enough to also furnish steam for running a drill pump or pulsometer. The trestles or towers are from 25 feet to 35 feet high and are spaced from 200 to 300 feet apart, the distance depending upon the amount of work that is in progress at one time.

A noteworthy feature of the Carson Cableway is the wide range of operation possessed by the hoisting buckets, as they can be raised or lowered at any point under the line of the cable, and a horizontal motion can be given to them at any point. This wide scope of the buckets permits the excavation of an extremely wide trench and also of a curved one. Fig. 85 shows the excavation of a 20-foot trench.

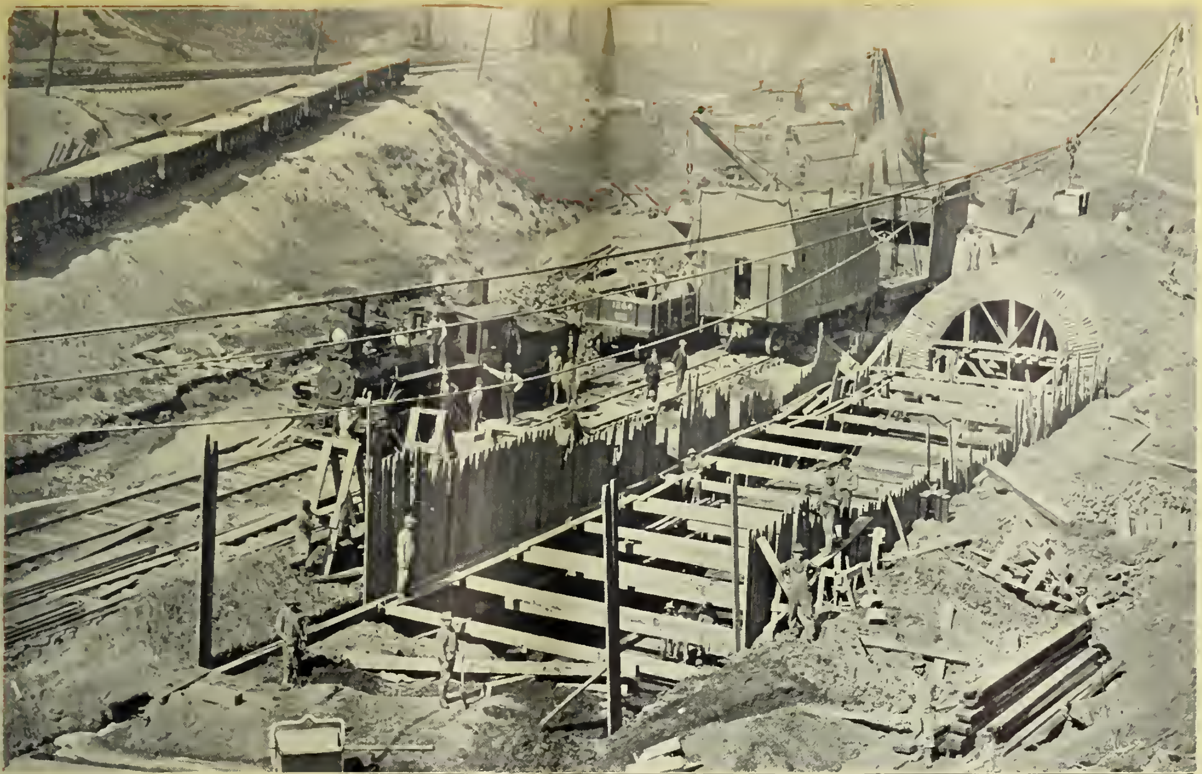


Fig. 85.

The output of the cableway depends entirely upon the character of the excavated material and the number of men at work. The number of men is, however, limited to the number than can conveniently work in the trench. But with using two one-yard buckets, about 30 cubic yards per hour can be stated as the average capacity. A loaded one-yard bucket can be hoisted at the rate of 250 per minute and transported at the rate of 400 feet per minute.

There are many advantages of the cableway system which are indeed worthy of note:

(1) The earth is handled but once and the surplus earth left after the trench has been refilled can be conveniently dumped into carts and carried directly away.

(2) All the trenching operations are carried on directly over the excavation, and thus neither the streets nor the work in

Fig. 86.

the trench is obstructed. This is an important feature, when excavation is carried on in crowded city streets, as traffic is not entirely obstructed, and the contractor has free access to all parts of his work. The height of the cableway above the streets permits the passage of vehicles while work is being carried on.

(3) It is very well adapted for excavating extremely wide trenches, where long and heavy timbers whould be necessary in order to support an excavating machine. As the cable towers are light, the danger of the banks caving in is reduced to a minimum.

(4) Cableways are well suited for difficult cases of sewer excavation, as crossings of railway and street-car tracks and where there are numerous service pipes. They can be used in any kind of material and can even convey large boulders weighing over two tons, and hence can be advantageously used in raising and

lowering heavy materials such as iron pipes, rock drills, etc. Fig. 86 shows the lowering of a 36-inch pipe for sewer work.

(5) The cableway system, while extremely efficient, taking the place of from 30 to 40 men, is comparatively simple and there are few parts that easily become worn and need repair.

(c) Trestle Systems:

While trestle systems have been in operation in America since about 1880, they have not, upon the whole, gained special favor with American contractors. This is perhaps due to the fact that the American contractor's paramount idea, power, is not as readily conceived of in them as in the various other systems of trench work. They are, however, very prominent in trench work in the Eastern States at the present. Many makes of these machines are upon the market, but only one, perhaps the leading one, The Carson, will be described here.

There are two general forms of the Carson machine, manufactured by the Carson Trench Machine Co., of Boston, Mass., which are termed the Carson Trench Machine and the Carson-Trainor Hoister and Conveyor. They are very similar in design, the main difference lying in the form of trestle used. In the former the trestle is rectangular, and in the latter it is A-shaped. The general construction of these two forms can be seen from the accompanying illustrations.

The track is hung from the top of the trestles and consists of two riveted channels resembling an I-beam. The track is constructed so that the space needed for the movement of the buckets is brought high enough to allow the operations, with building the work, to be carried on unhindered below. Fig. 90 shows the Carson-Trainor machine in operation and illustrates how easily

Fig. 87.

Fig. 88.

Fig. 89.

Fig. 90.

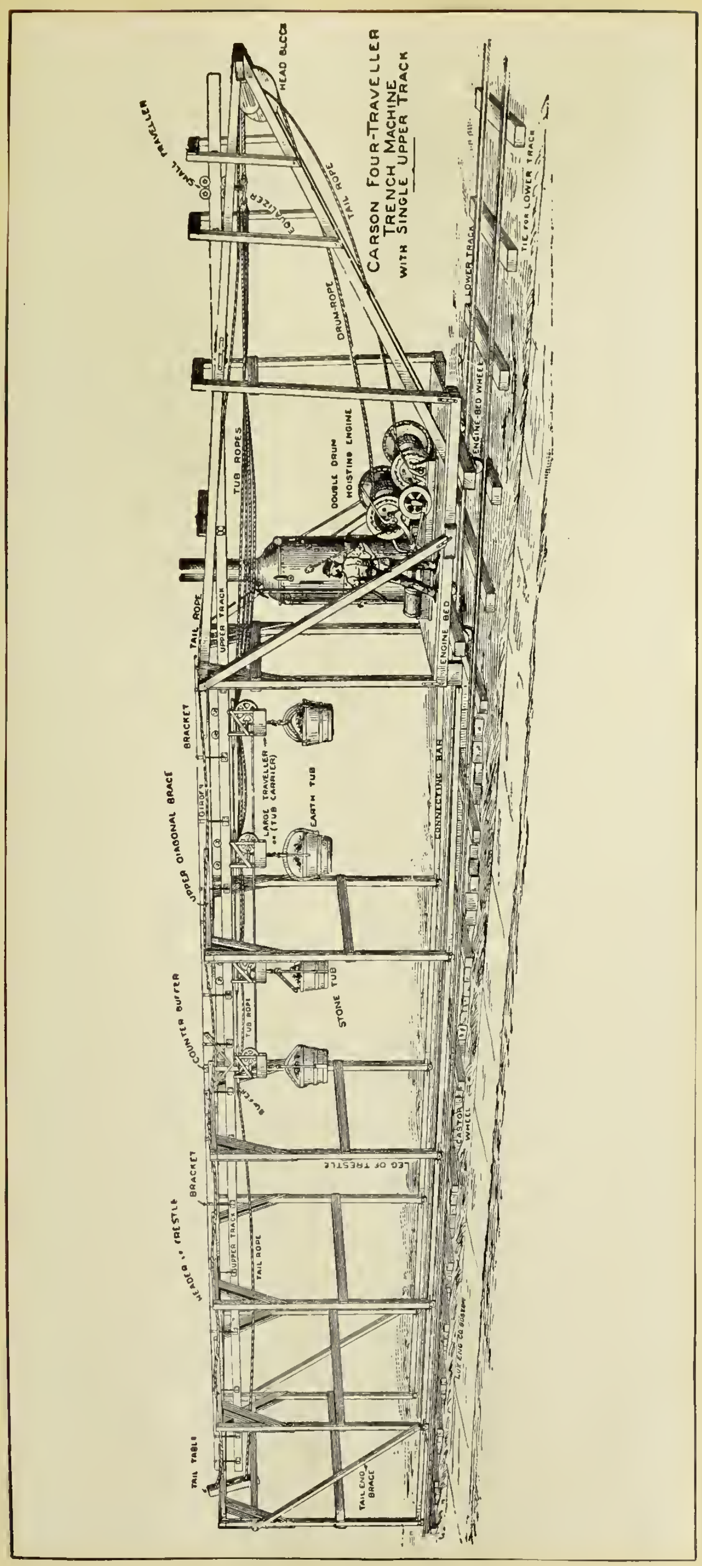

CARSON FOUR-TRAVELLER
TRENCH MACHINE
WITH SINGLE UPPER TRACK
HEAD BLOCK
SMALL TRAVELLER
EQUALIZER
TAIL ROPE
DRUM-ROPE
TUB ROPES
DOUBLE DRUM
HOISTING ENGINE
ENGINE-BED WHEEL
LOWER TRACK
TIE FOR LOWER TRACK
ENGINE BED
TAIL ROPE
UPPER TRACK
BRACKET
UPPER DIAGONAL BRACE
LARGE TRAVELLER
(TUB CARRIER)
EARTH TUB
CONNECTING BAR
STONE TUB
TUB ROPE
COUNTER BUFFER
BUFFER
LEG OF TRESTLE
CASTOR WHEEL
BRACKET
HEADER OF TRESTLE
UPPER TRACK
TAIL ROPE
TAIL TABLE
TAIL END
BRACE

Fig. 91.

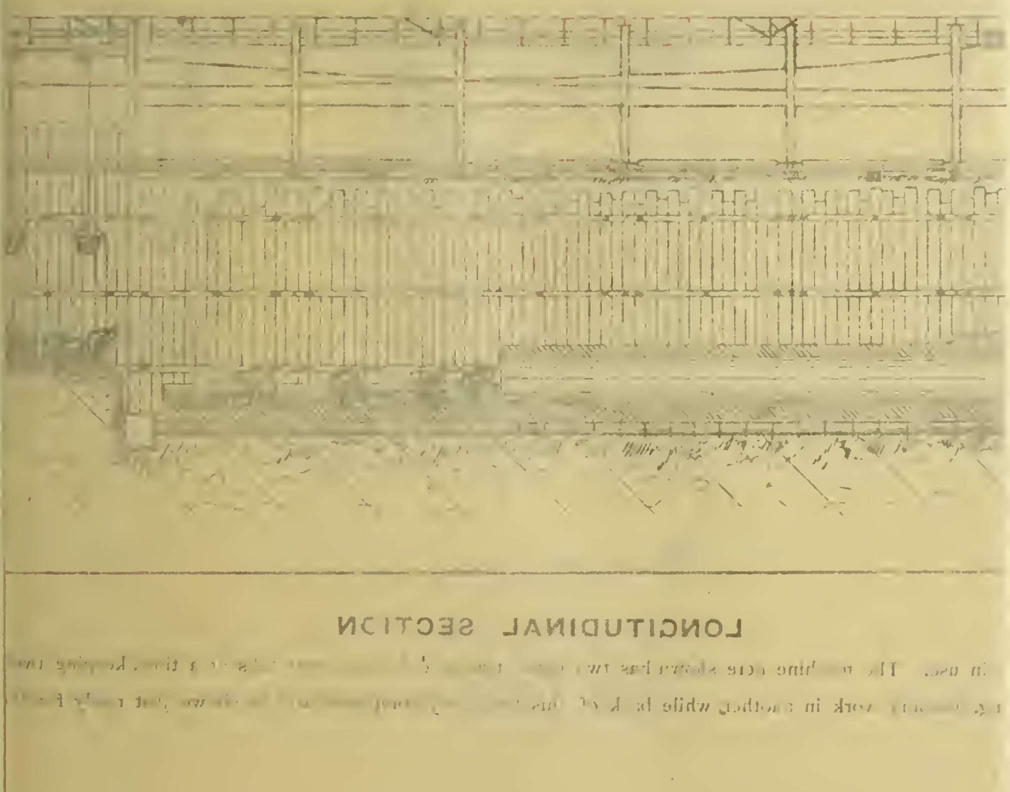
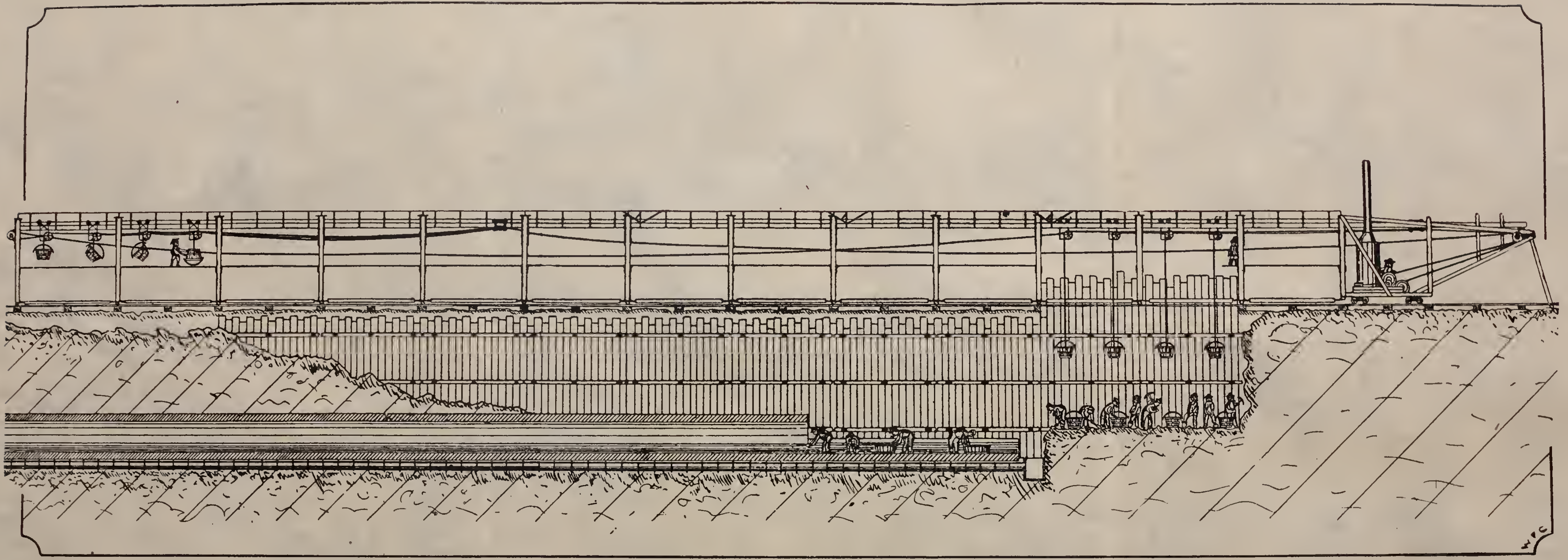


Fig. 92.



LONGITUDINAL SECTION

Of sewer trench where a **CARSON TRENCH MACHINE** is in use. The machine here shown has two upper tracks, and hoists four tubs at a time, keeping twelve tubs in continual use.

Excavation is going on in one division of the trench thirty-two feet long, masonry work in another, while back of this the newly completed arch is shown just ready for the backfilling. The distance between the trestles of the machine is sixteen feet or four and eighty-eight hundredths meters.

teams may pass under it. On the lower flange of these channels run travelers from which hang the conveying buckets which are propelled by an endless chain attached to a special drum of the engine. The travelers are usually connected in groups of four or six, and generally two groups are in motion at the same time. Each group has a separate track and two tracks are sufficient in most cases, as any desired capacity can be obtained by increasing the number of buckets and travelers in a group. In extremely wide trenches sometimes more than two tracks are used. In Fig. 91 is shown a perspective view of a four-traveler machine, with a single upper track, and in Fig. 92 is a longitudinal section of a Carson machine.

Outside of the trestles and track, the working of this machine is almost identical with the cableway. It is adapted to a little heavier work and is just as systematic and compact in its operations. The advantages are almost precisely the same as with the cableway.

When considering the use of trench conveying machines, many factors arise and that of economy is pre-eminent. Conveying machinery is economical only when the cost of operation, including all labor but that of the men digging in the trench, and of repairs, plus the rental or interest on first cost of the machine is less than the cost of staging plus that of the backfilling. If the backfilling is to be hand-tamped, this last item should not be included, since if a machine is used, the material must be spread after dumping. The question of which type of machine to use depends largely upon personal considerations, conveniences at hand, and the character of the work. But in general there can be no distinct limitations to this system of trench work.

(3) Excavating and Backfilling Trench Machines.

The idea of a combined excavating and backfilling machine, while a comparatively old one, has not as yet been very highly developed. It is very obvious that there is an enormous demand for such a machine, as the work of either the excavation or backfilling is exceedingly slow and laborious when it must be done by hand. Up to the present time there has been only one such machine built that has in any way proven satisfactory. This machine is the Libbe Trench Excavating and Backfilling Machine, which is the invention of Mr. J. H. Libbe, president of the Libbe Engineering and Construction Co., of Toledo, Ohio.

When in operation the excavation is performed by a bucket or dipper similar to that of a dipper dredge, the bucket running on a traveler which is carried forward as the work progresses, and from the rear of which the material excavated at the breast may be dumped as backfilling.

The general design and construction of the machine consists of a steel carriage 30 feet long, which is mounted upon flanged wheels running on a track of a gage which can be varied according to the width of the trench. Upon this carriage is built the steel frame supporting the runway for the dipper. This runway is lowered into the trench for any desired depth of cut, the upper and lower legs being connected by a curved portion of a 15-foot radius. Within the runway travels a trolley to which is attached the bucket, and a steel cable is fastened to the bucket and leads to a drum of the engine, which is mounted upon the carriage. At the rear end of the upper part of the runway is a pivoted section forming an automatic dumping platform, the weight of the loaded bucket tilting the platform, which is then returned to its original

position by a counterweight. The empty bucket then returns by gravity to the bottom of the trench. If an open trench is desired, an arrangement is provided for depositing the material at either or both sides of the excavation. Suspended from the frame of the traveler is a sheeting or lining set up by screw trench braces which are released when the machine moves forward. This sheeting dispenses with the use of the ordinary sheeting and bracing, as all work is done under its protection and no timber is left in the trench. The sewer pipe or other material is lowered through the carriage, and the men engaged in laying the pipe are thoroughly protected by this sheeting. The sides of the trench are always left very smooth and true. The machine is fed forward after each cut by a cable anchored ahead and wound upon a drum operated by the engine.

The machine is capable of operating in hard material at the rate of about one cubic yard per minute. An engineman and two laborers are all the help needed to operate it. The weight of the machine, including the engine, is about 10 tons. A canopy over the machine protects the work during bad weather. It is very efficient in its operations and should in time, if sufficiently developed, be the typical drain and sewer tile machine.

The problem of maximum efficiency in trench work is composed of numerous factors, the chief of which is, perhaps, the question of which system to be employed and the type of machine to be used. In order to obtain the highest efficiency with any machine it must be designed to perform some special work, since no machine can exercise its maximum power when working under general conditions. Ranking next to the above factor is that of management of the work and control of the men. While the control of

the men deals especially with the personal element of the management, due consideration should be given to it, however. The factor of time is also important because it is fast becoming the controlling question on much large work.

AERIAL CABLE TRANSPORTATION

Before considering the descriptions, adaptabilities, and limitations of aerial transportation, it should be stated at the outset what is meant by wire-rope tramways and also by cable conveyors.

Wire-rope tramways comprise the different systems of the transportation of material in suspended buckets by means of wire-ropes or cables, more generally applicable to the longer lines in which a number of such buckets are carried continuously at different intervals, determined by the individual loads, varying up to a ton in weight, and the amount of material to be transported in a given time.

Cable conveyors differ from wire-rope tramways in their adaptability to the moving os single loads of several tons weight over comparatively short distances. It is with the former type, however, with which we will deal here, because the capacity of its work is so enormous.

The simplest form of wire-rope tramway is that known as the single-rope tramway, in which one rope performs the double function of support and means of propulsion for the hanging buckets. This system was invented in 1868 by Mr. Charles Hodgson, and it is yet referred to as the Hodgson single-rope tramway. The buckets in this system are suspended from saddles consisting of light, malleable-iron boxes containing blocks of rubber or wood which bear on the rope. The box-head is fitted with a couple of grooved wheels on one side, and these wheels serve to lift the box-head from the rope at the stations, by engaging shunt rails

supported by the framework of the stations. The terminal points of the shunt rails are bent down and so placed as to come under the wheels of the boxheads, receiving those entering the station which are lifted onto the shunt rail by the momentum of the buckets, and depositing the departing ones onto the rope. The buckets are conveyed by hand along the shunt rails to convenient points of loading or discharge, as the case may be, while the rope continues running.

The power is transmitted to the traveling cable by means of a grip wheel, the rim of which is fitted with a number or continuous series of toggle-jointed steel jaws. These jaws bite the rope by reason of the pressure of the same against them, but as soon as relieved of this pressure they open, thus offering no resistance to the egress of the rope.

The earlier single-rope tramways wer indeed very crude affairs, the aim of these constructions apparently having been cheapness rather than efficiency. The consequence has been that they have given but indifferent satisfaction, and in some instances have proven flat failures, which has deterred many from adopting this method of transportation.

It is obvious that a system where one rope both supports and propels the loads can only be adapted to comparatively light duty, as otherwise the tension necessary to maintain a reasonable amount of deflection between the supports would overstrain the rope. Because of this fact the single-rope system has failed to meet the demand for increased and heavy outputs.

In such cases it becomes necessary to use independent, stationary cables for supporting the buckets in which the material is carried, a lighter endless traction rope being employed to move

the buckets over the line. A second, although lighter, tramway is needed to return the empty buckets. This latter system, in its general application, is known as the double-rope tramway system.

The double-rope tramway system was invented a few years after the single-rope system by Mr. Adolph Bleichert, a German engineer, but it was not introduced into this country until about 1888. It is the double-rope system, however, by its improvements and its advantages that has gained the name and won the favor that aerial transportation has acquired in Europe. It may be here stated that while aerial transportation is today meeting with much favor in America, it is in Europe that it has thrived in its development and operation. This is due to the accessibility and greater readiness of the railways in America to extend branch lines to newly developed sections and industries along their route. In America,also,many have been deferred from adopting this form of transportation because of the impression that the aerial lines are detrimental to property interests. This last difficulty will be more readily appreciated when it is understood that wire-rope tramways have to be run in straight lines; and while angular bends are practicable, they are onjectionable as ordinarily constructed, because stations are required at such points and men are needed to pass the buckets around the deflecting sheaves.

The necessity for attendants will be better understood from an examination of the ordinary bucket for conveyance of ore, coal, and other similar materials, with the carriage from which depends the hanger in which the bucket is carried, and the grip for attaching the hanger to the traction rope, the whole constituting what is known as the wire-rope tramway car. The buckets

are self-dumping, Fig. 93, and may be self-dumping and self-righting, Fig. 94. The former, which are somewhat lighted and cheaper than the self-righting buckets, are generally used, since it requires little or no effort on the part of the operator in loading to right and latch the bucket. Self-righting buckets are only required in cases where the construction is such that it is inconvenient for the operator to attend to both righting and loading the buckets, or where the empty bucket in returning enters the loading station close to the ground, and there would be insufficient clearance for the ordinary buckets to come, as they do, upside down. In either case the latch that secures the bucket is disengaged at the desired point of dumping by a specially designed tripping bar attached to the track, cable, or station rail, as the case may be, the bucket being so hung that it instantly turns over and discharges its contents. In dumping along the line at a high elevation between supports, at a considerable distance apart, this tripping bar is generally attached to a frame, Fig. 95, guyed to the ground by wire ropes, in order to prevent the rebounding of the cable in dumping and consequent possibility of the carrier being thrown off.

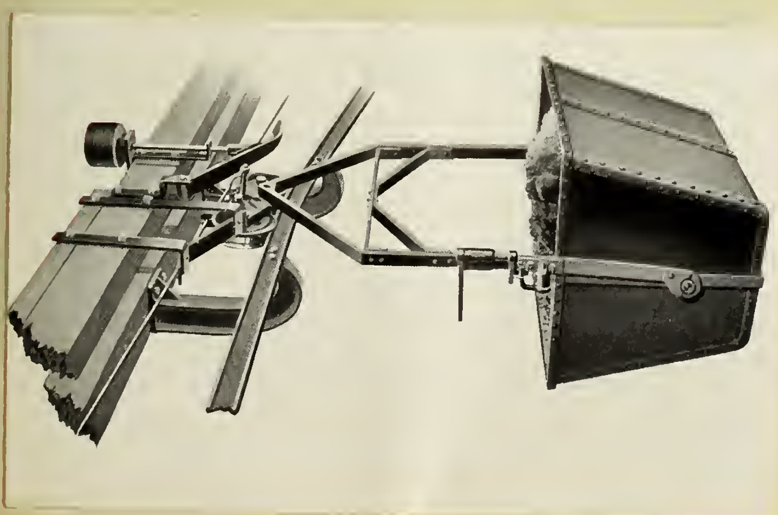


Fig. 93.

Fig. 94.

Fig. 95.

Fig. 96.

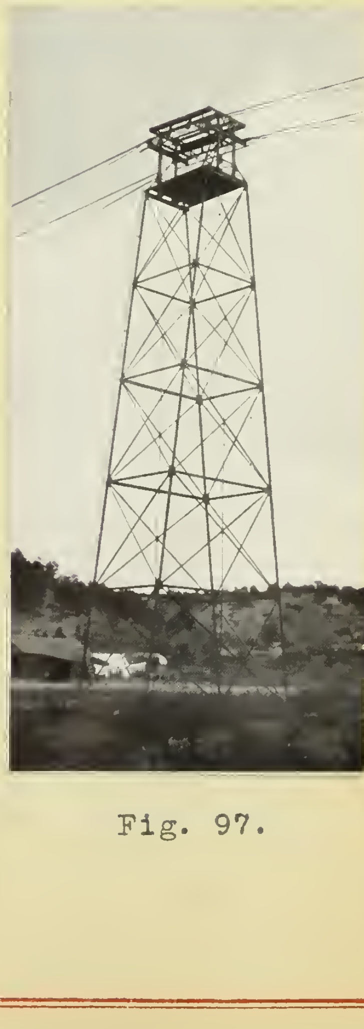


Fig. 97.

The supports are of wood, Fig. 96, or steel, Fig. 97, and the spacing of them is governed by the contour of the ground and the capacity of the line. Over level ground the distance apart will vary from 200 to 300 feet. In mountainous localities where the contour is rugged, the distances between the supports will vary greatly being closer on the ridges and wider apart in the valleys.

In crossing ravines, valleys, and rivers, spans have been made exceeding half a mile, and in Fig. 98 is shown one of 2 400 feet in length. However, spans of 1000 feet are very common. Long spans are not objectionable provided the loads are not so great as to produce too sharp an angle at either support.

In lines of considerable length it is necessary to apply tension to the track cables at intermediate points on account of the saddle friction. Special structures, known as tension stations, are erected for this purpose, at which the track cables are parted, the ends of which are rigidly anchored or counterweighted. These stations are of timber, Fig. 99, or steel, Fig.100, construction.

The stations of the tramway are so designed and equipped as to make the operation of the tramway as nearly automatic as practicable, so that little labor is required. Ordinarily the only stations required are the terminals, one where the buckets are loaded and the other where they are discharged, designated respectively as the loading and discharge terminals.

It is often desired, however, to load or discharge at intermediate points, in which case stations are erected and so designed that the carriers may be derailed from the traction rope and run along shunt rails for such purposes. Lines of great

Fig. 98.

Fig. 99.

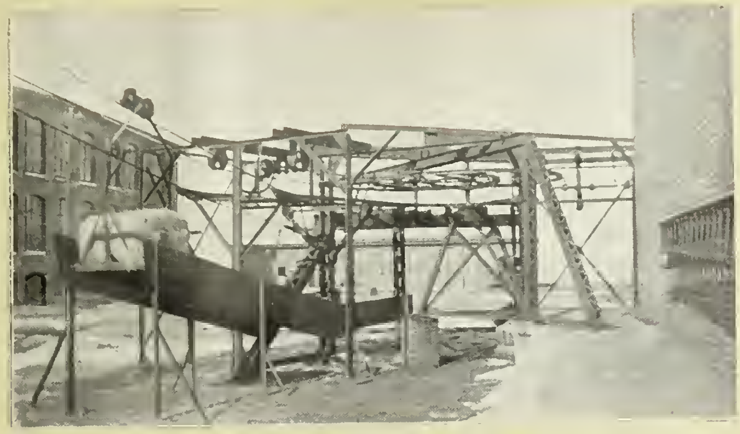
Fig. 100.

length or very heavy capacity sometimes have to be divided into sections, owing to bends in the line or on account of the stress in the traction rope which, if operated in one length, would be so great as to preclude the ordinary sizes of the rope such as the grips are constructed for. If angles happen to occur in such a line, the intermediate stations are most advantageously located at such points.

The buckets upon arriving at any station are automatically detached and shunted to overhead rails, by means of which they are taken to the various points of loading or discharge, and thence to the opposite cable, where they are attached mechanically to the traction rope and again sent out over the line. A good conception of the workings of the station can be obtained from the various views at the end of this section.

In selecting the route for any line it should be distinctly borne in mind that it is impracticable to operate along curves, and that differences in vertical elevation, no matter how rugged the ground, are seldom considered as obstacles to a perfectly straight course. It is not always possible, however, to obtain the right of way for a straight course, and bends are made in such cases, but it should be clearly understood that such bends are only practicable by angles, and that every angle requires a station for supporting the necessary deflecting sheaves and shunt rails. With overhead grips the buckets, if desired, may be passed around the sheaves without detaching from the traction rope, but it is necessary in such cases to use sheaves of large diameter. With underhung grips the buckets must be detached from the traction rope upon entering the station in order to pass the deflecting sheaves, and be re-attached in dispatching them

from the opposite sides. Intervening shunt rails are used for this purpose and an attendant is required to pass the buckets and grip them to the traction rope, and hence such stations add not only to the first cost, but also to the cost of operation. A good view of an angle station is shown in Fig. 101.



Fir. 101.

Lastly, we must consider the advantages of the double-rope system of tramways.

(1) It is adapted to the heaviest traffic. Capacities up to 200 tons per hour can be transported, which is not possible with any other system of aerial tramway.

(2) The buckets are moved under ordinary conditions at speeds varying from five to six miles per hour. This is about double the speed possible with a single-rope tramway.

(3) The loading and discharge of the buckets at either terminal or intermediate station can be effected at any point or any number of points.

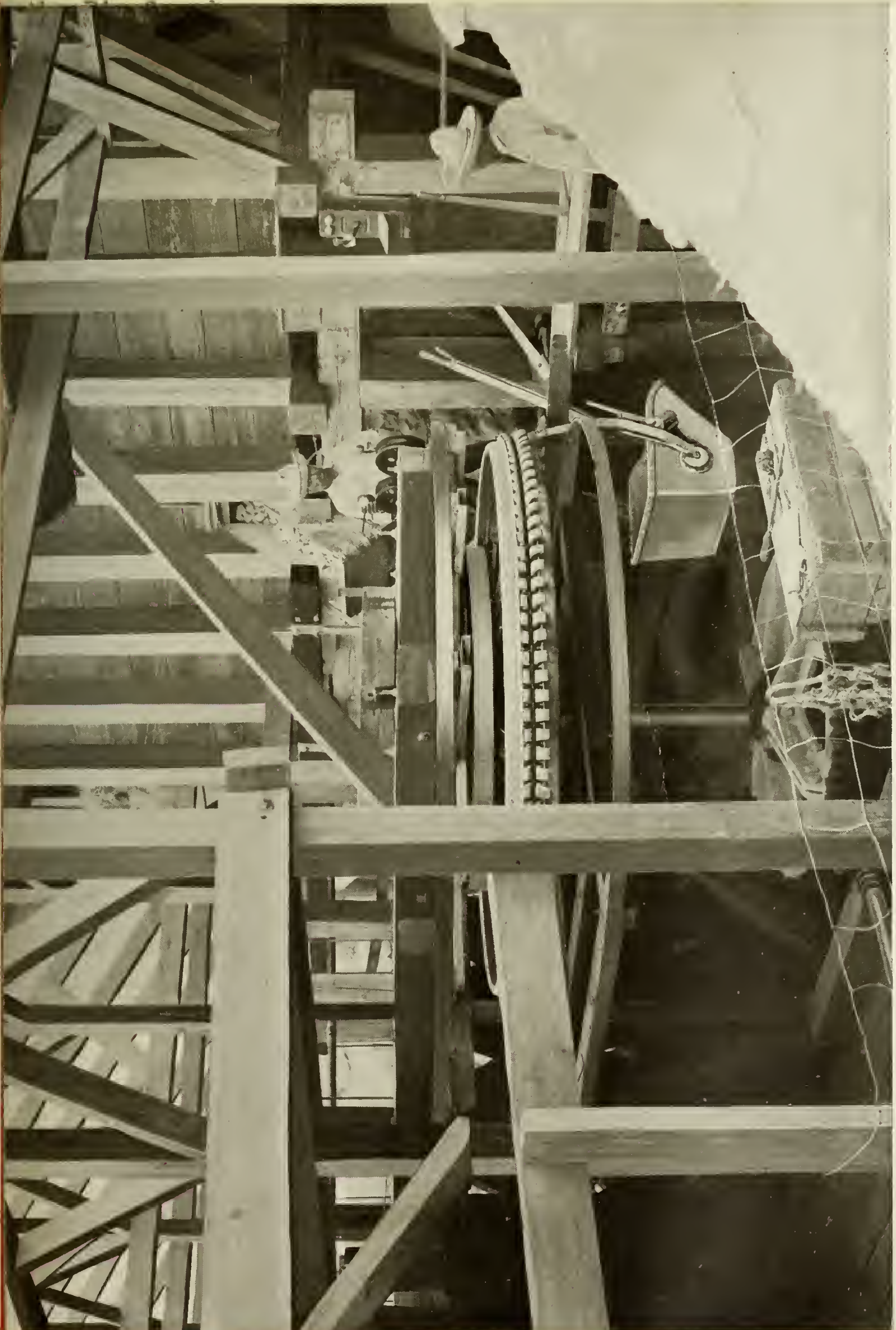
(4) The steepest grades can be surmounted without difficulty.

(5) Less power is required than with any other system.

(6) The cost of operation and maintenance is low compared to the single-rope system.

The use of aerial rope tramways for the transportation of material fom one point to another constitutes one of the most economical methods of conveyance upon the market. Heretofore wire-rope tramways have been confined, with a few exceptions, to the transportation of ores, in the mountainous sections where railroads are too costly to be built, owing to winding detours, bridges and cuts, and also where the elements operate against railroad construction. Their field of operation is not, however, limited to the mining industry, as they can be just as economically used in industrial plants, cement works, lumbering districts, etc. Judging by their good work in the past and their increasing popularity, they are destined to become the means of conveyance of material that must be transported a considerable distance.

The following illustrations are descriptive views of a Leschen Company's Special Automatic Tramway Installation across



Interior detail of loading terminal. Bucket approaching mechanical loader to receive the ore. The traction rope grip wheel is 10 feet in diameter and is equipped with cast steel grips to secure necessary friction. Inexpensive power is supplied by 45 H. P. gas engine, the gas for which is derived from charcoal burned on the ground.

Fig. 102.

View over line from loading terminal. From mine, ore is hauled five miles by wagon to this point, weighed by Mexican customs officials and dumped into storage bins.

Fig. 103.

Detail of discharge terminal shows its simplicity of construction. Overhead rail around which bucket passes is provided with tripping device, causing the automatic discharge of ore into pockets under the floor. The sheave wheel at this terminal is mounted in a tension carriage with weight box attachment, for maintaining constant and uniform tension on the rope. No attendant necessary.

Fig. 104.

Loaded and empty bucket passing on line. There are 90 buckets now employed, carrying 7½ tons ore per hour. The number of buckets may be increased to make a capacity of 10 tons per hour. Buckets are attached to traction rope by means of universal clips which provide a grip so positive that it is impossible for the bucket to either become disengaged or to slip.

Fig. 105.

Sixty-foot tower carrying cables over sharp rise in the foreground. In determining the heights of towers and selecting their location, great care was exercised in order to produce a line which was even, as well as easy on the slopes.

Fig. 106.

Filling water carrier. Detail shows wherein, when necessary, a switch diverts the carrier from the main track to permit the tramway to continue without interruption. These carriers are fitted with friction grips and can be attached to the line at any point between buckets as may be convenient.

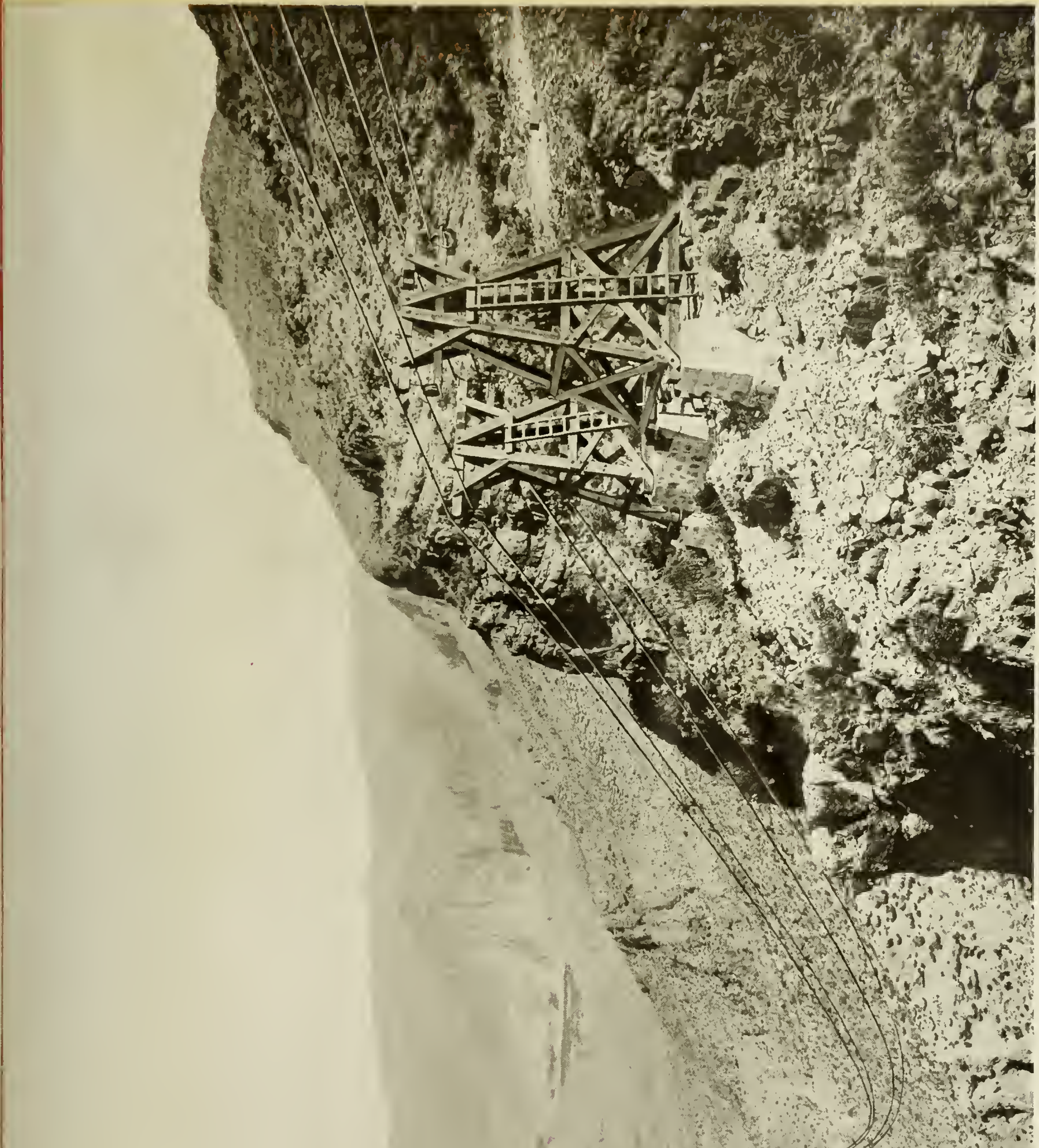
Fig. 107.

Crossing Rio Grande River looking toward Mexican side. This span is 1,300 feet long. Just beyond first tower is tension station, fitted with water tank where water carriers are filled. To the right of it is the pumping station.

Fig. 108.

The track ropes of this tramway are 1 inch diameter on the loaded side and ¾ inch diameter on the empty side. Crucible Cast Steel material, Patent Flattened Strand construction. Patent Flattened Strand construction is especially adapted to this character of service, having greater strength and a large, smooth wearing surface, due to which the Wear on both rope and rolling stock is reduced to a minimum.

Fig. 109.



Double towers set on masonry base near loading terminal. The spacing of towers is necessarily determined by the contour of ground. Within this view are both the shortest and longest spacing of the line, the latter being a 1,500 foot span.

Fig. 110.

Loaded bucket beginning its six-mile journey. At the lower end of loading terminal is shown gas engine mounted on masonry base.

Fig. 111.

DREDGES.

The most important questions to be taken into consideration in all projected schemes for either the construction of harbors, docks, and canals, or for river and drainage improvements are those of dredging operations and the forms of appliances best suited for the existing conditions. The conditions under which dredges operate, and the work they must perform, are extremely varied and exacting. Almost every combination of circumstances within the range of engineering experience may be encountered, and, in fact, many obstacles are encountered which prove to be of the most formidable nature. The material in which they are forced to operate ranges from soft, fine mud to large, hard rocks, and from loose sand to sticky clay. All impediments must be reckoned with, so as to cause the least delay to the existing conditions of navigation and drainage, and also to bring about the quickest improvements.

Dredging operations are generally carried out with one of the following objects in view: (1) to prepare the surface of the ground under water for receiving the foundations of some structures, such as break-waters, quay-walls, bridge piers, etc.; (2) for deepening or widening some existing canal or river; (3) for cutting a new river course, canal, or channel, or diverting existing ones; (4) for removing obstructions to navigation, such as bars at the mouth of a river, harbor, or dock; and, (5) for removing the deposits which accumulate from different causes after any of the above operations have been completed.

The types of dredges are nearly as varied as the operations, but naturally there always exists a characteristic relation-

ship between them and the particular class of work for which they are designed, because, for instance, a very different type of dredge is used for rock work than would be used for dredging sand. Notwithstanding these facts, dredging machines may be classified according to their principles of operation, namely: (1) Digging Dredgers, or those in which the action is that of cutting and raising by means of buckets, and (2) Hydraulic or Pneumatic Dredgers, those in which the action is that of erosion and suction by means of pipes.

Digging Dredges.

The first digging dredge, termed the bag and spoon, was indeed very simple in design. This dredge was first employed by the Dutch people in cleaning their numerous canals through which their internal traffic is carried on. The dredge itself consisted essentially of a large leather bag, kept open by a heavy iron ring, called a spoon, which was fastened to the end of a large wooden shaft. A rope was attached to the iron ring and by means of a hoisting engine the bag was dragged along the bottom of the river and then hoisted to the deck level, where the material was dumped into the hold of the barge. In order to make sure that at each haul the bag was properly filled, artificial weight was applied when the bag was at the bottom of the river by temporarily lashing the projecting end of the staff to the side of the barge. The usual capacity of the barge varied from one-half to one cubic yard, and in order to operate it a gang of from five to eight men were employed. The maximum capacity of such a dredge was about one hundred tons per day.

Another early form of the digging dredge was a large, spoon-shaped shovel which was dragged across the bottom of the

waterway by means of ropes fastened to two barges moored at some distance apart. Upon the barges were windlasses, by means of which the shovel was hauled along the bottom of the waterway and up an inclined plane to the deck, where it was emptied and then drawn back by the windlass upon the other barge.

There were various other forms of digging dredgers, each adapted to different details of dredging operations, but it was not until about 1800, when the first steam dredger was built, that any marked progress was made in this line. The digging dredgers of today, which are the direct outcome of the application of steam to this kind of work, are of three classes, viz.: (1) elevators, or endless chain dredges; (2) dipper dredges; and (3) bucket dredges.

(1)Elevator Dredge:

The elevator, or ladder dredge, was first used in 1778, when it was employed in cleaning the old dock at Hull, England. The first elevator dredge driven by steam was designed for cleaning Sunderland Harbor. It consisted of a flat-bottomed boat 80 feet long and 20 feet broad, and had a 5-foot draught. It had a single ladder with twenty-nine buckets, and was operated by an engine with a cylinder 18 inches in diameter with a 24 inch stroke, which made 40 strokes per minute. Under favorable conditions it was capable of dredging 120 tons per hour, but the average capacity was about 45 tons per hour. This dredge has been continually developed and we now have the powerful dredge of today, capable of dredging about 1000 tons per hour.

The work performed by the ladder dredge is of five distinct classes: (a) the ladder dredge, when equipped with a long

conveyor for delivering into scows, is used to a great extent in the excavation of narrow cuts, or in shallow water where the depth is not great enough to float scows alongside the dredge. (b) When combined with a series of conveyors, it is very efficient in the excavation of channels through river and lake beds where the point of delivery is quite distant from the dredge. (c) In canal work, where a wide berm is required, it is without an equal. In this work conveyors are used to carry away the material. (4) It is very efficient for excavation or land reclamation, where the point of delivery is far from the dredge. In such cases it is equipped with suction pipes for conveyors. (5) There is a special dredge designed for excavation in gold-bearing placers.

Dredges of the elevator type are equipped with either one or two ladders. In single ladder dredgers the center line of the ladder coincides with the longitudinal axis of the vessel, and in the other case the ladders are set at each side.

A side-ladder dredge can work in a greater proximity to the face of a vertical wall than is possible in the case of a central ladder. While a central-ladder dredge can discharge indifferently to either side, if any mishap occurs to a link or bucket, the whole dredger is put out of action, whereas in the double-ladder dredger one ladder may be quite disabled without interfering with the balance of the work. If the material to be dredged is very stiff, it is possible that the double dredger may have an advantage over the single-ladder, because if the tumbler can be arranged so that the two ladders are not doing their heaviest work simultaneously, the power required to operate two smaller ladders would probably be less than that required to work one of equal capacity of the two. Nevertheless, the greater fric-

tion of the double machines might outweigh any of the above advantages. For heavy work double dredgers are certainly preferable.

A single-ladder dredge of the same capacity as a double dredger has the advantage of fewer moving parts, and consequently of less working friction. The central position of the single ladder admits of a more convenient outline for the vessel. The broad beam of the double dredger renders it difficult for it to pass through narrow locks, although this difficulty has been overcome by constructing the dredger in detachable halves. As a rule, single-ladder dredges are smaller machines than the double ones. One the whole the balance of evidence favors the single-ladder type for general use, and most modern dredgers are equipped with central ladders.

Fig. 112.

The central-ladder dredge consists essentially of an endless chain having a series of scoops or excavating buckets attached to it at regular intervals. The endless chain turns around two tumblers placed at the extremities of the ladder. The chain carries the filled buckets to a considerable elevation, where they are discharged. The methods of discharge differ greatly from each other, according to the depth and purpose of the excavation. A common method is to discharge into spoil-wells in barges run alongside, or into the dredge itself. Fig. 112 shows the dredge discharging into a accompanying barge. The transporting conveyor is called the self- or barge-loading chute. Another form of shoot, called the long chute, is used to discharge the material into an enclosed spot which is to be reclaimed. Other methods used to transport the spoil mechanically are the transporting platform and a system of floating pipes or a combination of floating pipes and land pipes. The former method is used to load wagons waiting on the bank, and the latter to deposit the material on shore.

Fig. 113.

The transporting elevator platform shown in Fig. 113 consists of beams guiding and supporting an endless band composed of steel plates connected by pins. The dredge discharges the material upon this band, the band being driven by an independent steam engine. The platform is used to discharge the dredged material directly upon shore whenever the banks are low and within reach. If the banks are quite distant, the material is first discharged from the dredge-hull conveyor upon a second conveyor on board a barge or scow and thence upon a third conveyor upon a second scow and so on until finally the banks are reached. An illustration of this latter method is shown in Fig. 114.

Fig. 114.

Another similar conveyor, of recent design, is the rubber

belt conveyor, which is capable of transporting muddy or even liquid material. This conveyor consists of a great number of rollers formed of steel tubes. On these rollers runs a heavy rubber belt made especially for this purpose. The rollers are carried by improved, dirt-protected, balanced bearings. A small belt about 120 feet long can be supported entirely from the dredger. Some of these conveyors are so constructed that they are capable of revolving, and thus can be used on either side of the dredger.

Floating pipes, or a combination of floating and land pipes, are used for discharging the material into the sea at some distant point, or on shore, by pumping. The spoil raised by the buckets is discharged directly from the upper tumbler into a reservoir containing bar screens which break up the material and prevent large stones and boulders from entering the pipes. An independent centrifugal pump delivers a large volume of water through a series of jets, pulverizing and breaking up the material, which can then be dealt with by the discharge pump. The discharge pipes are led over the deck and connected to the floating pipe-line by a flexible joint. The floating pipes are supported by floaters, and are connected together by many flexible joints in order to allow a free motion to the dredge and to each floater. When the dredged spoil is discharged into the sea the end of the discharge pipe should be moved from time to time, so as to distribute spoil equally over the site. This motion can be obtained by means of chains and anchors, or by hydraulic deviators or propellors. Whenever the spoil is to be delivered on shore, the floating pipe-line is connected to a land pipe-line laid upon the beach or supported upon a trestle. The length of such pipe lines is generally 1000 to 2000 feet but may be increased to as long as 6000 feet.

The formof the hull of the dredge depends entirely upon the work. The length is closely related to the dredging depth and also to the capacity of the spoil-well which the hull incloses if it is a sea-going hopper-dredge. Whenever the dredge has to pass through a narrow dock entrance, its width is limited, but when it operates entirely in an open sea, it should be wide.

The bucket chains are of two types, the open and the close connected. The former consists of buckets and links alternately connected. This is the type which is used for general work. The latter type is a through connection of buckets only and is used for especially soft and homogeneous mud. For dredging in many different kinds of soils, some dredges are constructed so as to have two sets of buckets, which differ only in their bucket capacity. An excellent view of the buckets of a central-ladder dredge is shown in Fig. 115.

The strong point of this style of dredger lies in the fact that its action is continuous. When the work is of sufficient extent, it can deal with extremely large quantities of material at a very rapid rate. It is very remarkable how much material can be excavated at such a low cost when the mechanical inefficiency of the machine, which absorbs so large a proportion of the working expenses in the cost of repairs, is considered. It appears, however, that this inefficiency is caused by mechanical difficulties and is not inherent in the system.

It has been stated that the operations of the ladder dredge are limited by draught. This is, in fact, true in a great many cases, but a new dredger has recently been built which overcomes this defect by having the ladder supported by a horizontal longitudinal framing capable of being projected in advance of the

Fig. 115.

the dredger, and thus enabling it to cut its own floatation through shallow places. The dredger cannot, however, work when the water is so rough as to cause much oscillation of the boat.

The most serious objection to this type of dredger is its waste of power. It is far from being an economical machine in this respect, because, owing to the necessity of its having to lift the material to a height sufficient to allow it to slide down the chute of the receiving hopper by gravitation, work has to be performed nearly one-hundred percent in excess of that required to lift the material to the hopper level. Sticky material, such as clay, requires a fairly steep chute, and even then some manual labor must be given from time to time to aid the material in its descent.

The ladder dredge has not as yet gained as great favor in this country as has the single-dipper dredge. This fact is due to the excellent work that has been performed by the latter in the hands of experienced specialists here. The principal attention of the contractor has thus far been devoted toward these machines, and the ladder dredge has yet to come into its own. Nevertheless, of digging dredgers the ladder dredger stands foremost in importance. It is on the whole the most satisfactory realization of an appliance for dealing with all kinds and conditions of material in an efficient, economical, and expeditious manner. There are other types, it is true, that are better suited for special kinds of work, but as an all-around machine the ladder dredger stands unrivalled.

(2) Dipper Dredge:

The dipper dredge of today is a development of the old Indian jham. The jham consisted simply of a large spade into the

top of which was fixed a handle also secured to the spade by a rod. When in operation, a native stood with his feet at the top of the spade, holding the handle firmly in both hands, and then dove to the bottom of the stream, where he pushed the spade into the ground. When he had pushed it in as far as possible, he ascended to the surface, where by means of a rope attached to the jham it was hauled up and its contents emptied. This primitive design of the dipper dredge has since been superseded by many ingenious appliances, the most important of which has a single, fixed bucket attached to a handle working on a large boom. The dipper dredge of today is almost exclusively an American machine.

Dipper dredges may be classified according to their size, as each is adapted to slightly different kinds of work. (1) This class comprises the smallest size of dredges, having dippers from one-half to two and one-half cubic yards capacity. They are used for constructing canals, drainage ditches, and similar work, and may have either bank or vertical spuds. (2) In this class are included dredges whose dippers have a capacity of from two and one-half to four cubic yards. Such dredgers are used principally for deepening and maintaining channels in harbors and rivers. (3) This class comprises the largest sizes, with dippers of from four to twelve cubic yards capacity. The machinery of the dredgers of this last class is extremely heavy and powerful. The dredgers are adapted principally for harbor work and for the removal of rock ledges and other exceptionally hard material. They are capable of digging to a depth of 30 to 55 feet.

The general construction of the dipper dredge is shown in the accompanying illustrations. The simplicity of construction should be noted, as it is due to this fact and to its cheapness

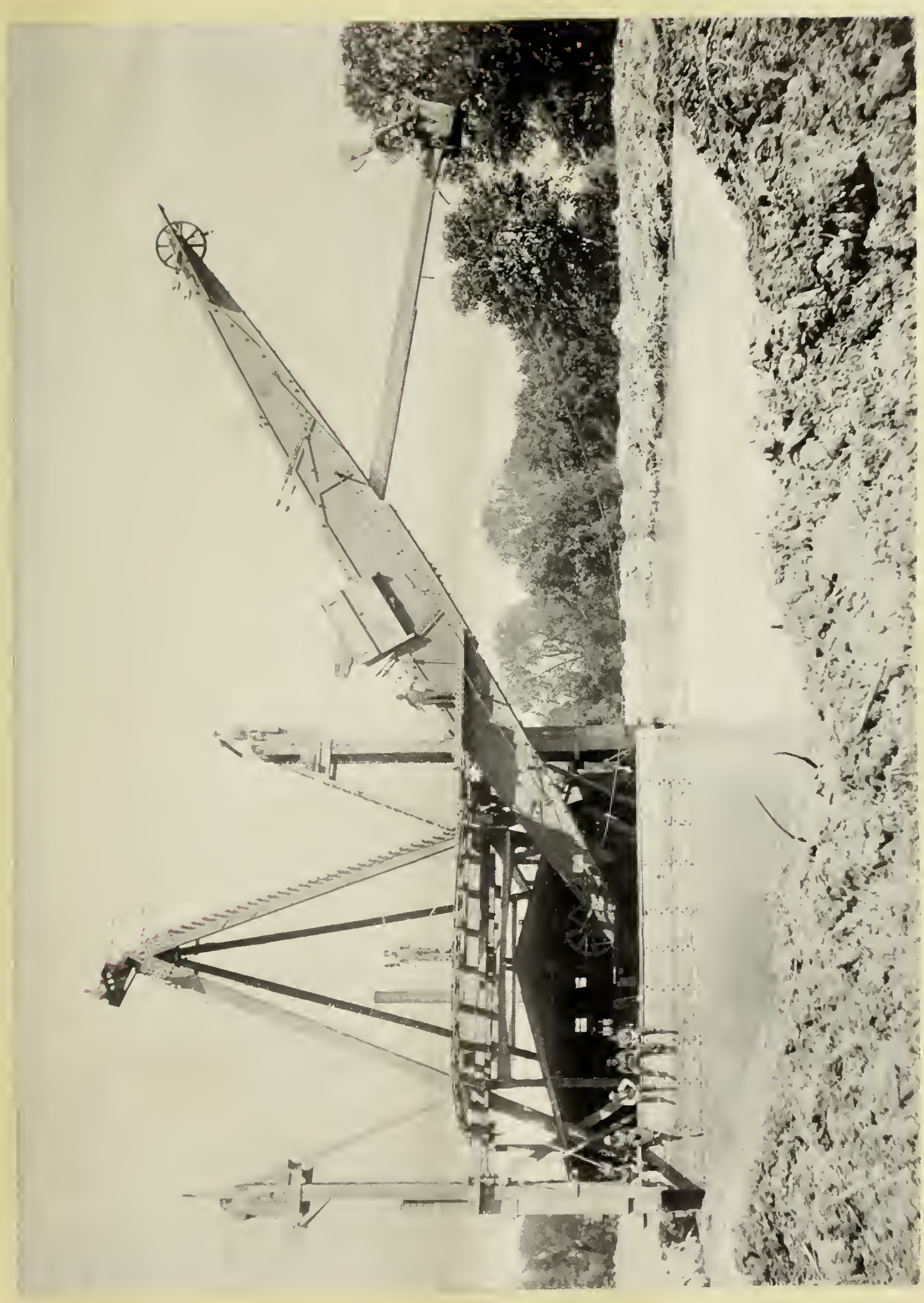


Fig. 116.

Fig. 117.

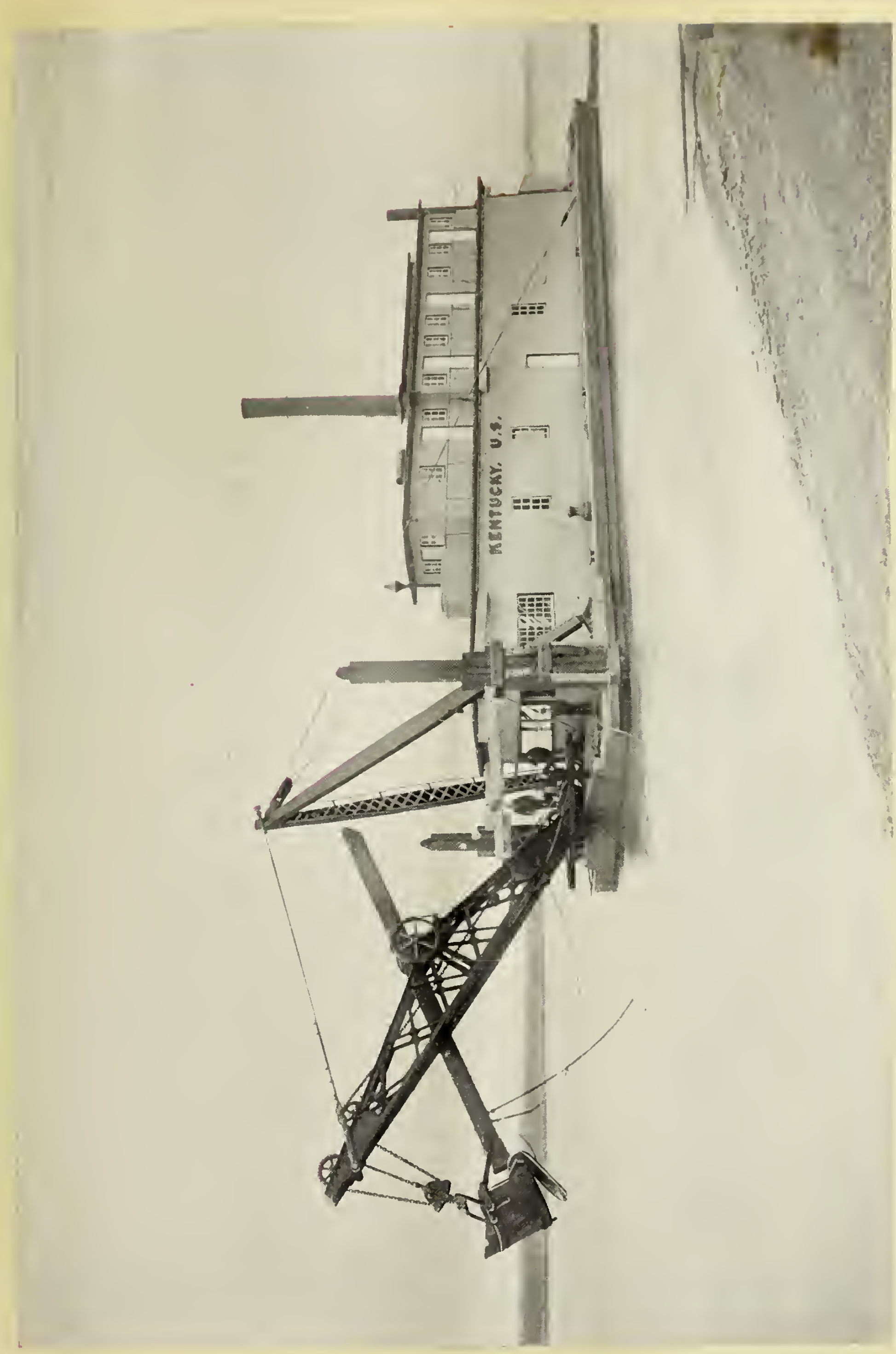


Fig. 118.

that the dipper dredge has become the great favorite that it has with the American contractor. The boom is made of either wood or steel, as the contractor chooses, but a great advantage of the wooden boom is its lightness in weight. The boom on different machines varies in length from 50 to 100 feet, acording to the nature of the work. The dipper handle which works through the boom is generally of wood reinforced by structural steel shapes. The buckets vary in size from one-half to twelve cubic yards capacity. The latter size, although exceptionally large, has been used on much large work. The buckets are controlled by wire ropes passing over the end of the boom, over the A-frame, and down around a special drum of the hoisting engine. This drum is equipped with safety appliances, thus placing the buckets at all times under complete control of the operator.

The 10 cubic yard dipper dredge shown in Fig. 119 is one at work in the canal of the St. Lawrence River Power Company. The bucket of the same dredge is shown in Fig. 120. The dredge has 18 inch by 24 inch double main engines, especially designed to handle the large dipper at extreme depths. The boom and A-frame are built of structural steel shapes and are of unusual strength. The dipper handle is of oak, heavily reinforced by structural steel, and is of sufficient length to reach 30 to 55 feet below water level. Each side of the dipper handle consists of two 12 inch by 12 inch oak timbers, reinforced by 12-inch channels and with a 12-inch open-hearth steel rack. Included with this machinery are two steel trusses running fore and aft in the hull, which effectually strengthens it against the digging strains and those stresses experienced when the dredge is working in a sea-way. These heavy and powerful dredges have proven entirely

Fig. 119.

Fig. 120.

satisfactory and represent a distinct advance in design and construction over any similar machines that have as yet been built.

The A-frame, which holds the boom in place by means of wire ropes, may be of steel but preferably of wood. It is stepped upon the upper deck on top of the spud casings in such a way that when the dredge is pinned up, practically the entire thrust upon it is carried to the spuds. This arrangement causes the stresses resulting from the thrust to be carried through the spuds and not through the hull of the barge. This arrangement is, however, only applicable when the dredge is working in a narrow ditch. A good view of such an arrangement is shown in Fig. 121.

The spuds are almost always of wood and are about 50 to 75 feet in length. They are operated by two ropes attached to a drum, which is fitted with a powerful friction clutch and brake and is operated from the engine. The entire power of the main engine is available for handling the spuds and pinning up the machine. Although they are extremely heavy they can both be raised simultaneously and with good speed, and without difficulty, as all the operations for throwing the clutches and brakes are performed by steam.

A cross-sectional view of a dipper dredge at work is shown in Fig. 122. The variety of work that can be done by one of these dredges is surprising to one unfamiliar with them. The dipper dredge is, in fact, a complete floating crane of 50 tons capacity. It is easily adapted for pulling piles, tearing out old foundations, or preparing for new ones, and for lifting heavy weights of all kinds. Buried timber or sunken wrecks which would block a ladder dredge are rooted out by it and lifted with ease. Where large boulders are encountered, it is necessary to pass a

Fig. 121.

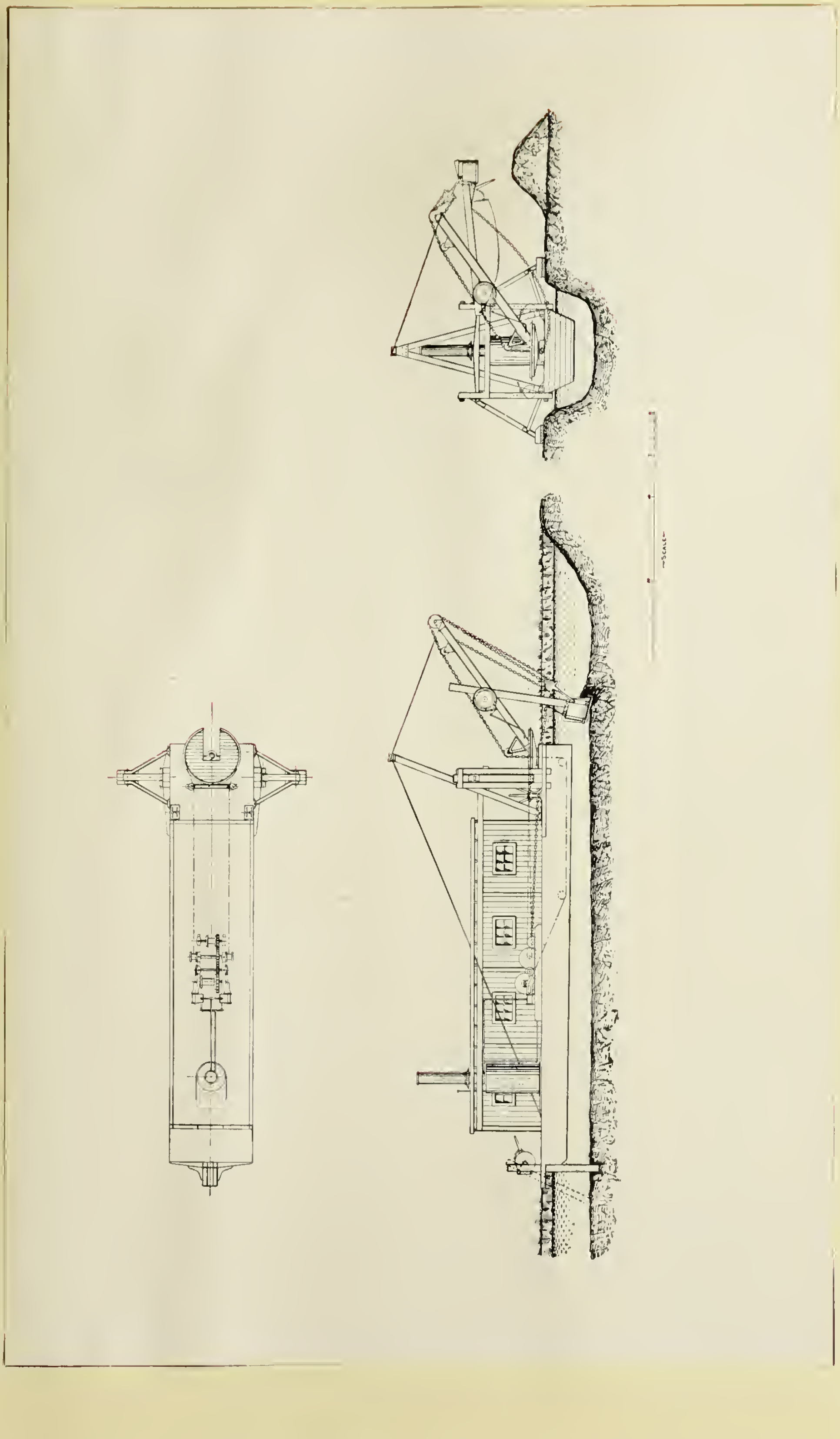


Fig. 122.

sling chain around the boulder and catch the sling on the teeth of the dipper and lift. For rock dredging a small and very strong dipper is used, and for soft material the dipper may be two or three times as large, of lighter construction, and without teeth.

The process of moving the dredge forward consists in raising the spuds and dropping the dipper on the bottom of the waterway as far forward as possible and then pulling in on the backing chain. The rear spud remains on the bottom while moving up, in order to keep the dredge in line. For this purpose it is generally made to roll in a fore and aft direction and when so made is termed a walking spud. Should the dredge, for any reason, get off line, a swinging or lateral movement imparted to the dipper while moving up will correct this error. The moving-up process should be accomplished in a minute by a well designed dredge.

With all its capabilites the dipper dredge is indeed simple and is at all times under the absolute control of one man who is captain, engineer, and the soul of the machine. Hence the effectiveness of the dredger depends upon the skill of the operator. Speed and continuity of action are necessary to good results, and in order that these requirements be maintained, the mechanism is made very quick in action and instantly responsive to the will of the operator without much manual labor on his part. The operatow must be the brain and not the muscle of the machine if top speed is to be always maintained. The speed of a good dipper dredge may be said to be about 40 seconds per dipper load.

The dipper dredge has the serious objection of having an intermittent discharge. Much time is lost between its consecutive outputs. This is especially true in work where only light cutting

is required, and hence is very inefficient, as the bucket is only partially filled at each stroke of the dipper. Its capacity is not as great as the ladder dredge. It is impossible for the dipper dredge to cut as exactly to grade and leave as smooth a bottom as does the ladder dredger. Nevertheless, the dipper dredge has a decided advantage over the ladder dredge in that it is not so complicated and hence is less liable to accidents. It has the advantage of reducing the height of the lift of the material as compared with the ladder dredge. It is independent of the variation of the water-level due to the tides and waves. It is extremely powerful and is capable of cutting its own way through almost any kind of soil and in any direction. This type and the various bucket dredgers are the only dredgers that will excavate rock of any considerable size. Any rock that cannot be excavated by this dredge, when it is desired not to blast, is broken up by a heavy steel chisel weighing from 10 to 15 tons. This chisel has a hard cutting edge and is let fall by its own weight from a suitable height upon the cleared surface of the work. Thus the rock is splintered and pulverized to a condition capable of being removed by the dipper.

(3) Bucket Dredgers:

The bucket dredge, like the dipper dredge, is a development of the old Indiam jham. The operation and performance of all bucket dredges is somewhat similar and their general construction is the same, only differing in the form of the bucket used. There are, at the present time, four general forms of buckets in use in the United States. They are (1) the scoop, similar to the dipper of the dipper dredge; (2) the clam-shell; (3) the orange-peel; and (4) the grapple. The following points,however, should

be noted in all bucket construction if the bucket is to perform its maximum usefulness: (1) It should penetrate the ground easily, without slipping and tumbling. (2) It should cause itself, when closed, to be full of earth. (3) It should open and close automatically. (4) It should close readily and tightly, permitting no leakage. (5) No earth should be washed over or drop out when being raised through water. (6) It should readily discharge its contents and not require cleaning. (7) It should be simple in construction, have as few wearing parts as possible, andbe easily repaired.

The Scoop Dredge, when used on land, is termed a drag-line excavator, and then differs from the scoop dredge only in the matter of its bearing, the former resting upon a car and the latter upon a boat. Therefore in this discussion the drag-line excavator and the drag-scoop will be considered as the same. The construction of the drag-scoop dredge,while very similar to that of the dipper dredge, differs from it in several ways, namely: (1)the dipper dredge acts away from its power and machinery while the scoop acts toward its engine; (2) The dipper is held rigidly to the face of the excavation by the boom and dipper arm; the bucket of the scoop dredge is loosely suspended from the end of the boom by means of blocks and cables; (3) the dipper dredge requires a smaller track than does the scoop dredge; (4)the scoop dredge works slower and is more awkward than is the dipper dredge. Hence it is seen that the two machines are not rivals.

The general construction of the scoop dredge is shown in the accompanying illustrations. It consists essentially of a large A-frame derrick carrying the bucket. The derrick is set upon a circular platform built of structural steel shapes. Beneath this

Fig. 123.

Fig. 124.

Fig. 125.

Fig. 126.

platform is a second platform, also built of steel, and at the center of this latter platform is a cast-steel bearing upon which is pivoted the upper platform. The derrick platform is arranged to revolve upon the steel bearing and upon a set of wheels spaced around the circle concentric with the center bearing. Each wheel turns upon an axle consisting of a radial rod attached to a cast-steel spider seated in the center bearing. The A-frame is anchored to the derrick with rods and is generally cross-braced to give it the proper rigidity. The derrick carries the boom, which is swung from the front end of the platform. The bucket shown in Fig. 126 is swung from the end of the boom by a three-part line wound around the drum of the hoisting engine which operates the derrick. The body of the bucket is similar to the dipper of the dipper dredge and is built of steel plates with a mouth-piece on the forward end of the bottom. In front of this mouth-piece is a heavy bail attached to the side of the bucket. The bucket is swung from the front by two chains on a block carried by two parts of the fall line. Each of the chains is fastened to one arm of the bail. At the rear the bucket is swung by a bridle chain which passes around the curved end of the bucket and is attached on two sides of the bottom.

The depth of the cut made by the cutting edge is gauged by the angle at which the rigid bail is attached to the bucket. The extent of the cut is readily changed by altering the position of the bail, while a curved steel shoe on the under side of the bail makes the cut of uniform depth. The two angles forming the brackets of each arm of the bail are arranged so that they can be extended or shortened, to change the position of the bail, by simply moving the bolt by which each pair of them is attached to the

side of the bucket.

Fig. 127.

The machine is operated by one man, who is stationed at the front end of the platform where all movements of the buckets are in plain view. The engine is controlled at this point by means of levers and clutches, which are operated by a steam ram. A view of this dredge operating at night is shown in Fig. 127. The operation of the dredge is as follows: When the boom is swung over the place where the cut is to be made, the scoop is dropped to the bottom of the water by slacking off on the fall line. As soon as the bucket strikes the bottom, it is in position to start cutting by being pulled ahead with the haul line. During this advance it is independent of the fall line and remains so until the bucket is to be lifted again. The curved rear end of the bucket causes the materials pushed into it to turn forward as the bucket advances, so the full capacity can be utilized at each

cut. The material,having a chance to move up toward the open top, is not compressed into corners from which it cannot be discharged in a quick, clean way.

When the bucket is loaded, it is hoisted by hauling on the fall line, the weight being distributed on the three parts of this line so as to make the bucket ride horizontally. During this hoisting operation the haul line is allowed to run freely and loosely. The bucket remaining horizontal and free from the drag line, permits material to be spoiled at any height without danger of its losing part of its load. After the derrick is revolved to bring the boom over the place where the spoil is to be deposited, the bucket is dumped by an arrangement of the three-part line, by which it is suspended. This line passes over a sheave at the end

Fig. 128.

of the boom and finally down to the rear end of the bucket,where it is fastened. On the under side of the boom and between the two

sheaves over which are passed the two parts of the line carrying the block, is a plate curved to fit the top of the latter. By continuing to haul on the line after the block is drawn up until it engages this plate, the pull comes on that part of the line attached to the rear of the bucket,with the result that the bucket is inverted, as can be seen from the various illustrations in Fig. 128.

In addition to the hoisting engineer, a fireman is all that is required upon the machine, but when operated on land, men to attend to the laying of thetrack are required. The dredge is moved ahead by employing the out-swung bucket as an anchor or by the use of land spuds, in which case it is often termed a walking dredge.

The Clam-shell Dredger of today is an improvement over the simple clam-sheel dredger that was first employed in California in the construction of harbors, docks, and in making various river improvements. This old-style dredger was known asa turntable dredge. The turntable was secured to a mast and was operated with a winding drum, the turntable having two projecting arms which spanned the boom about one-fourth of the distance from the pivot. It was also operated by a chain-lift to the bucket with a compound set of hoisting blocks. The modern dredger is operated by steel chains, which lead directly from the windingdrums to the end of the boom, thence to the bucket where they are connected direct without any blocks. This arrangement affords a better control of the boom, the pull from the end giving an increased leverage. The buckets of the old dredger were made of plate-steel hammered to the shape of clamsheels, while the buckets of today are made of cast-steel.

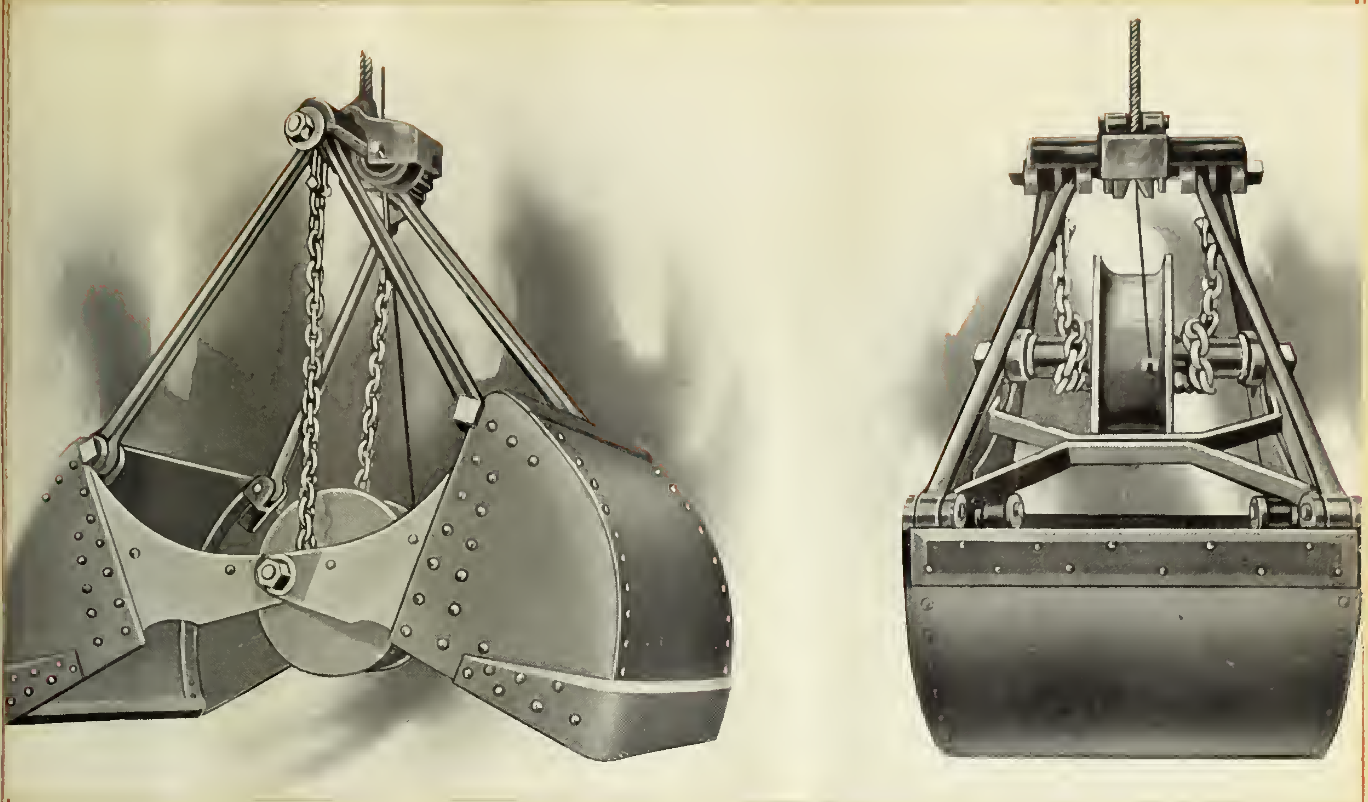


Fig. 129.

The construction of the modern clamshell bucket is shown in Fig. 129 and consists of two halves of a shell which rotate about a horizontal axis. Vertical arms are riveted on either side of the bowl and their upper ends are connected to the main shaft on which the power wheel for closing the buckets is located. The buckets are operated by two chains, one for opening and one for closing. The closing chain is attached to the periphery of a wheel or sheave mounted in the frame and arranged in such a way that a powerful closing action is obtained. The edges of the shell are forced into the soil by the weight of the bucket itself, and the pull upon the chain to raise the bucket draws the two halves together, thus forming a semicylindrical bowl which encloses the material to be excavated. This type of dredge is operated the same as the drag-scoop and is comparatively simple and strains its spuds considerably less than does the dipper dredge.

This type of dredge is used in preference to the dipper dredge when it is desired to bring up loosened earth in almost solid form and deposit it in an exact spot, so that an embankment may be built up solidly as the work goes along without waste of labor or material. It is well adapted for excavating in soft, homogeneous mud in deep water. When excavating in sand or gravel, heavier buckets are used. It is very often employed in pulling stumps, and when so used has short, heavy steel teeth riveted onto the closing edges of the buckets. The working of the dredge under several different conditions is shown in the following illustrations.

Fig. 130.

The ordinary chain closed clamshell bucket has several serious defects: the bucket can only be closed after it has come to rest upon the bottom of the water and the pull of the closing chains reduces the effective digging weight of the bucket owing to their lifting action. In the pneumatic bucket, a very recent

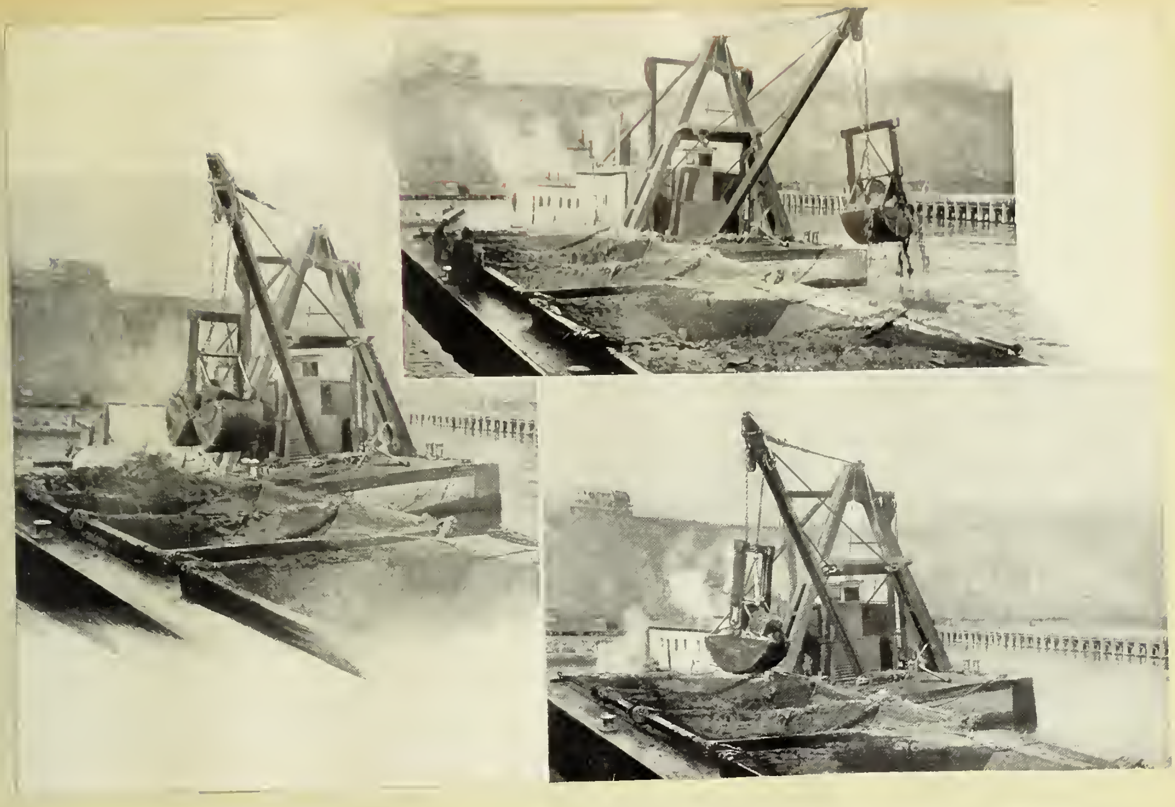


Fig. 131.

Fig. 132.

design, these defects are remedied by having the buckets closed by the action of liquid pressure in a cylinder. When in operation, the jaws of the bucket are both opened and closed by a positive action of the air pressure upon the botoom if the piston which is enclosed in the cylinder. Many advantages over the chain-closing type are claimed for this bucket and in essence they are: (1) the bucket can be lowered into a spoil-well of a scow and dumped upon the doors without dropping the load; (2) a gain of about 10 feet in the width of cut is made owing to the fact that the chain-closed bucket is on the bottom while closing; and (4) the ability to close the bucket at a given depth enables the dressing off of the bottom of the cut at the required depth without over-excavation.

The Orange-peel Bucket shown in Fig. 133 consists of a

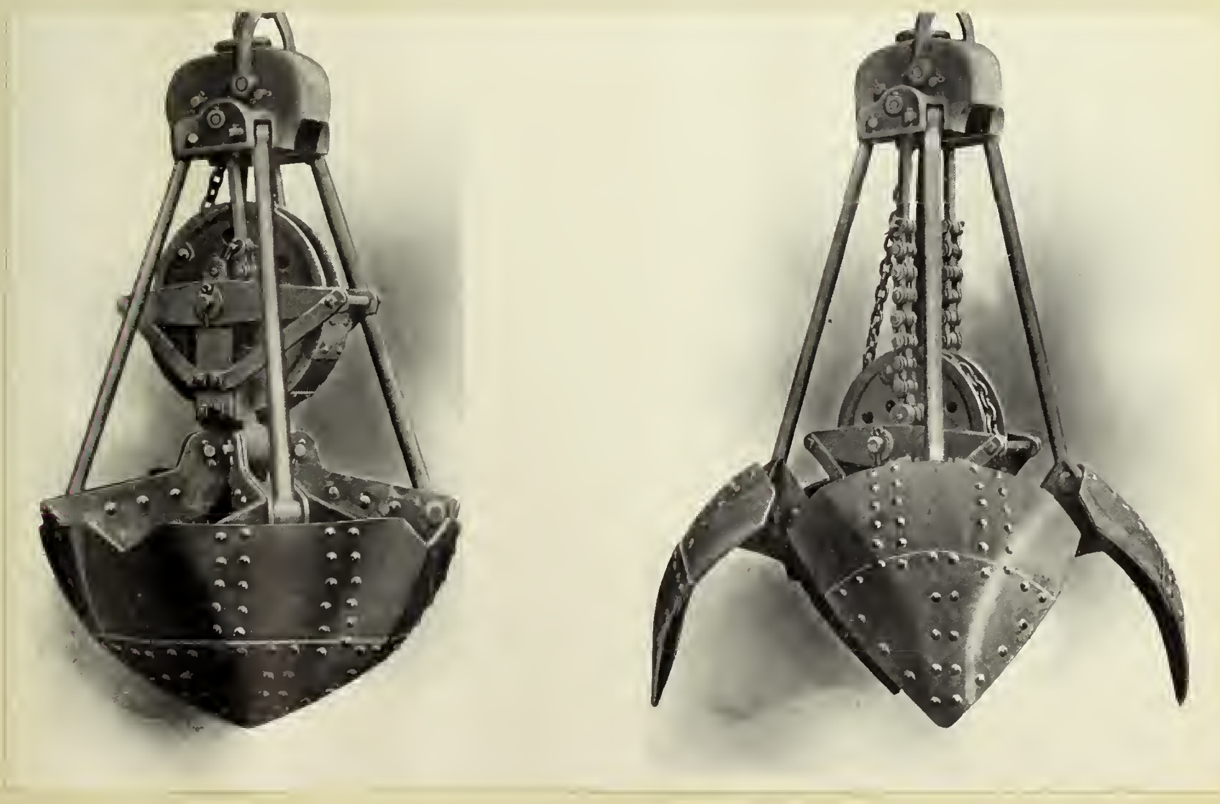


Fig. 133.

frame from which are suspended a number of spherical,triangular

spades which are forced vertically into the ground by their own weight. The pull upon the bucket required to lift it out of the ground draws these spades together, inclosing the excavated material. The bucket is constructed with three or more blades and when closed forms a tight semi-spherical bowl. It is, in fact, only a modification of the clamshell bucket. A dredge equipped with

Fig. 134.

with an orange-peel bucket is shown in Fig. 134. The orange-peel bucket dredge is used principally for unloading purposes and many times in connection with the clamshell dredge. It is also employed for excavating material that requires a considerable amount of digging power.

The Grapple, or whole tine grab bucket, is shown in Fig. 135. Its construction is the same as that of the clamshell except

that tines are substituted for the shells of the former. It is used in excavating hard clay, sand, blasted rock and boulder, for cleaning weedy growth from canals and rivers, and for other purposes where the maximum digging power is necessary.

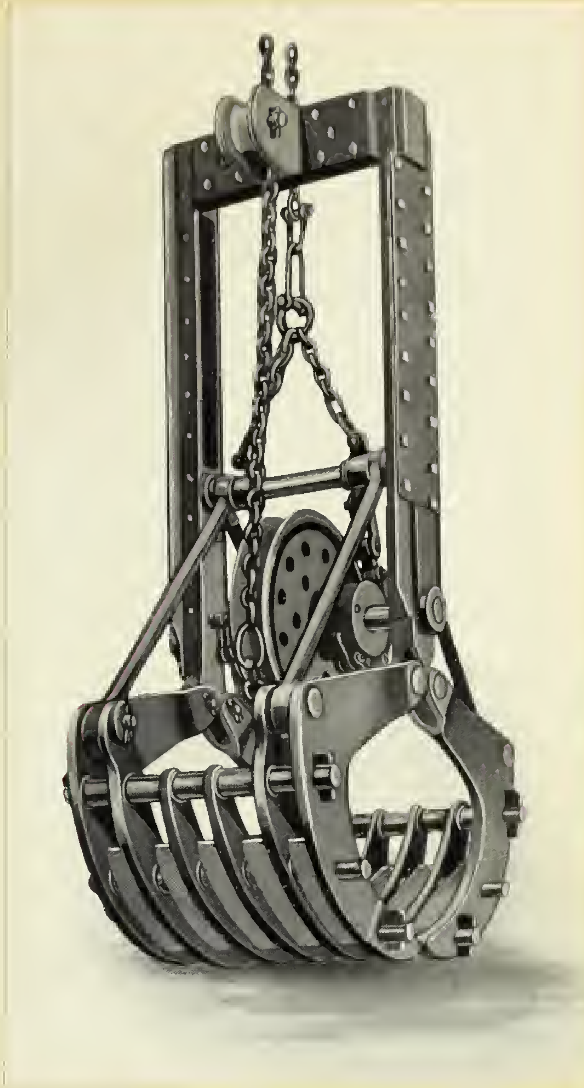


Fig. 135.

The field of operation of the bucket dredger is extremely wide, and it can be adapted to many special and severe cases of excavation. While the drag scoop dredge is at a decided disadvantage when compared with the dipper dredge in not being able to operate under such extreme adverse circumstances, it has the redeeming quality of not having to move very often. It can excavate from the top or from the bottom of the cut. The remaining types of bucket dredgers are exceedingly useful in working in wells, docks, or other confined spaces, and also for dredging a detached bar which extends over a comparatively small area. They lift the material with a smaller percentage of water than does any other type of dredge. The efficiency of the bucket to penetrate the material does not, however, depend upon the force with which it falls, because the jaws are so framed as to draw down and penetrate as soon as an upward strain is put on the lifting chain, when the

resistance of the soil is not too great. But if the resistance is great, the bucket is liable to slip along the surface instead of penetrating,and therefore it cannot be used in hard soils. Moreover, it is not suited for regular plain cutting, as it is designed to dig a number of consecutive holes, and its action is discontinuous.

Pneumatic Dredgers.

The application of the pneumatic system to dredging is the latest improvement in the manufacture of dredging machines. We owe its origin, like that of the elevator dredge, to Europe. One of the first forms of pumps used in dredging was simply a horizontal disk, with two or more arms, working in a case. This pump was somewhat similar to the ordinary centrifugal pump. The pump rested upon the ground and the suction pipe was so arranged that water was drawn in along with the sand or mud. The proportions of the two were regulated to suit the quality of the material. This arrangement was very effective in its time, but it has grown out of date and given way to the more powerful machines.

The development of the hydraulic or pneumatic dredge in America has resulted in the evolution of four special types: (1) the sea-going hopper type, without anchorage; (2) the lateral feeding, or ship channel type; (3) the forward feeding, or Mississippi type, with one or two forward mooring lines attached to anchors; and (4) the radial feeding, with spud anchorage.

Much progress has been made in the last ten years in the manufacture of sea-going hopper dredges. The earliest dredge of this type was used in the United States in 1855 at Charleston, S.C. It was a modern commercial steamboat converted into a dredge by the addition of centrifugal pumps, with necessary piping, etc., and

Fig. 136.

Fig. 137.

with spoil wells constructed in the hulls. Its drags, or suction heads, were somewhat similar to those now in use. While its capacity was small, its manner working was practically the same as is now followed. This type of dredge is used extensively by the United States Government and modern ones are shown in Figs. 136 and 137. The general construction consists of two large suction pipes situated on each side of the hull, the spoil-well on the interior, and the driving and suction machinery. The operation of the sea-going hopper dredge is as follows: The suction tubes are lowered to the bottom of the waterway and the air is exhausted from the centrifugal pump by an ejector. When the pump is charged, the pumping engines are started filling the tanks with water. The suction pipes having fed themselves into the bottom to a sufficient depth, the dredger is moved forward until the hoppers are filled with the dredgings. In order to loosen the material so that the suction pipes can secure it, the water-jets at the end of the pipes are kept in operation. When the hoppers are filled the suction pipes are raised and the dredge proceeds to sea.

The Lateral- feeding, Ship-channel type of hydraulic dredge is one of comparatively new design. A very notable and famous dredge of this type is the"J. Israel Tarte." This dredge is operated entirely by wire rope anchorage and the suction pipes pass through a well in the center of the vessel. The mooring ropes are arranged in such a manner that the operation is practically continuous. This dredge has the distinction of having made the largest output of any dredge in the world. It excavated 757 100 cubic yards of blue clay in 26 days from a depth of 35 feet and delivered it 2000 feet. When in operation, the dredge moves from side to side by means of its anchorage.

The Leviathan, which was launched in 1908, and which is, in fact, the largest twin-screw sand-pump hopper dredger in the world, will be described briefly here as a representative dredge of the forward feeding type. It is 487 feet overall and 30 feet deep and is capable of carrying a load of 10 000 tons of sand. The dredger is provided with pumps which are capable of dredging this load in 50 minutes from a maximum depth of 70 feet. Its propelling machinery is capable of driving it, when fully loaded, at the rate of 12 miles per hour. It is designed to carry its full load of sand as well as lumber, coal, and fresh water on a mean draught of 23 feet.

The vessel is built entirely of steel and is divided into 30 separate water tight apartments. The propelling machinery consists of two sets of inverted, vertical, triple-expansion engines, each having cylinders 37 inches and 61 inches in diameter with a stroke of 45 inches. The dredging machinery consists of four sets of inverted, triple-expansion engines coupled direct to four centrifugal pumps connected to their respective suction tubes, two on each side of the vessel with hydraulic sluice valves on the inboard side. Each tube is 42 inches in diameter and 90 feet long. They have 45 degree declination when dredging at their lowest level of 70 feet below sea level. Each suction pipe is lifted and lowered by two strongly built derricks of steel, one on each side of the tube. They are also supplied with an emergency gear, so that in case of accident the tubes can be lifted by block and tackle. Each hoisting winch has four drums, arranged in pairs, two for raising and lowering the suction pipes, and the other two for derricking inboard or outboard. The suction pipes are suspended from a double steel A-frame over the forward end of the spoil-well

and the lifting winch for raising and lowering them is carried on top of this frame. The suspension tackle is formed of two sets of heavy wire rope, the diameter of which are about an inch and a half. The sheaves are of cast-steel with turned grooves and brass bushings. The hauling parts of this tackle in this way pass direct to the drum of the winch without the intervention of any idler sheaves as would be the case if the winch was located below the deck. This arrangement has the further advantage of getting winch out of the hull where it would occupy valuable space.

The material is excavated by a rotary cutter the weight of which is about 5 to 10 tons. It is formed of steel blades with clearance spaces between them so as to avoid clogging with the material. The suction pipes and passages through the pump are made very large for the same reason. The cutter is driven by a pair of engines placed on top of the suction pipes at the upper end. They are of the most substantial construction, with all bearing surfaces extra heavy for continuous duty. The gearing and power transmission for the engines is of exceptional strength and is capable at all times of encountering immovable resistances with full head of steam on the engine without risk of breakage. A view of a common-sized forward feeding dredger is shown in Fig.138.

Radial dredgers are anchored by spuds and have a radial feed, the cutter describing an arc of a circle about the spuds as a center. The material, as in the two preceding types of pneumatic dredges, is principally discharged on shore at a distance through the floating discharge pipes. The entire suction pipe projects in front of the dredge and its lateral movement is accomplished by means of a block and tackle on each side, the hauling parts of which are carried to the drums of an auxiliary engine. The blades

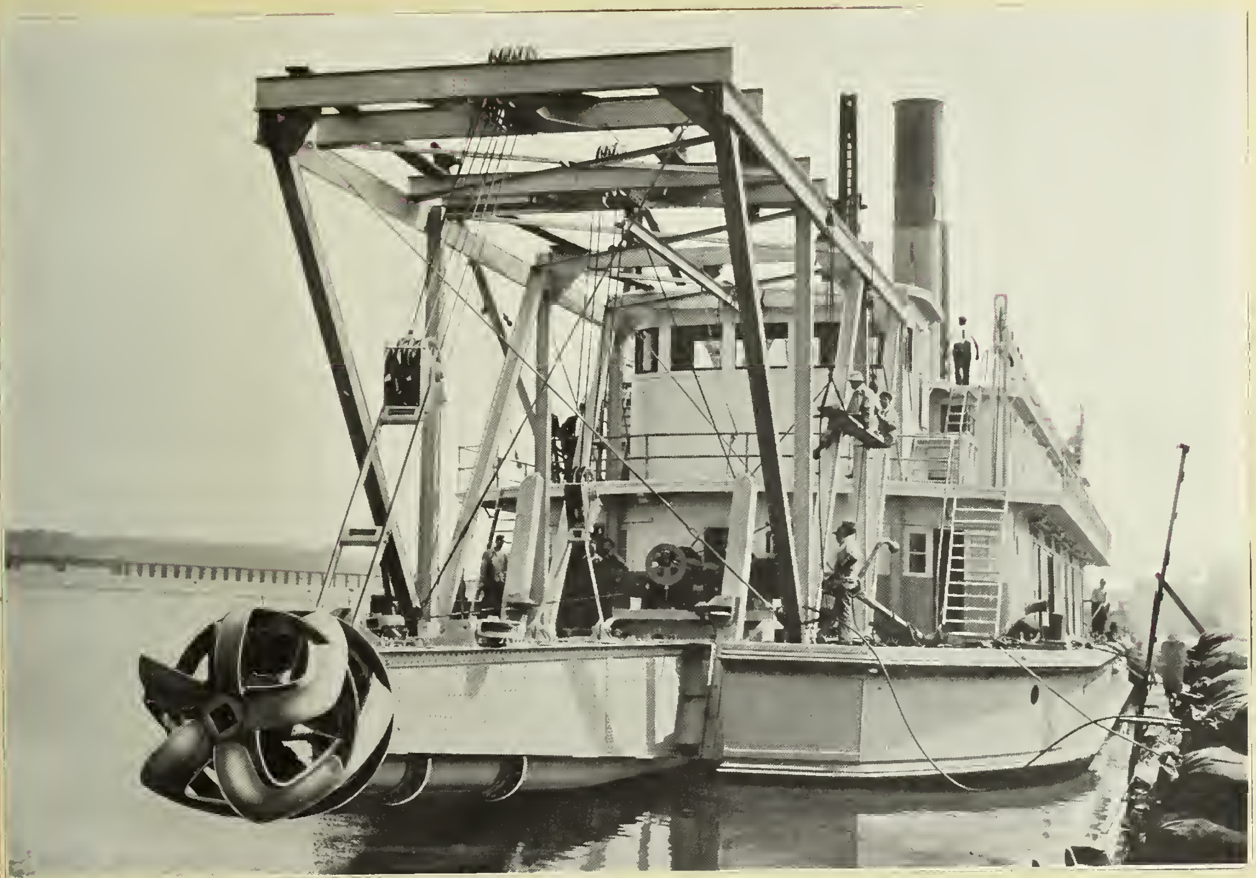


Fig. 138.

of the cutter, which is attached at the end of the pipe, are arranged on a spiral so as to give the maximum effect with the least liability of choking. The action of the cutter is such that the blades slice off or excavate the material and feed it into the interior of the shell through the openings, from whence it is removed by the pump suction. The cutter-head with its shaft gearing and all connections is of ample strength to stop the engines which drive them. Thus, in case of an immovable obstacle being encountered, nothing worse can happen than the stoppage of the engines. The suction pipe has a universal movement on the hull, so that it can raise and lower as well as swing. This movement is provided for by a section of rubber tube, where it passes over the deck, the suction pipe being attached to a revolving base plate on the bow of the dredge. The suction pipe, when swinging on its hull, can make a cut about equal in width to that of the hull, while the latter is anchored by its two spuds. When it is desired to make a wider cut, the suction pipe is secured in its mid-position, the swinging lines are carried out on each side of the vessel to a shore anchorage, and the entire dredge swings on its stem spud, thus making a cut from 150 to 175 feet in width. The spuds oscillate so as to permit the dredge to move up without drifting out of position, and when the move is made, they are lifted and dropped again in a vertical position and the work proceeds. The radial dredge is shown in Fig.139.

The pneumatic dredge has proven itself to be one of the most remarkable devices ever perfected for the removal of subaqueous material, which is at all adapted to its use, both in regard to the vast extent of its output and to the low cost of its operation. The results that have been achieved by the suction dredger,

Fig. 139.

during its as yet short life, are marvellous. In fact, on account of the unusual facilities offered by it for the disposal of the material, it has revolutionized the reclamation of low lands. The field of this type of dredger lies where the ground is soft and non-cohesive, and here its efficiency has been demonstrated beyond question. It has, nevertheless, been worked to a marked extent in coarse gravel and stiff clay. But,generally speaking, the suction dredger is adapted for use in homogeneous material, with or without the aid of mechanical agitators. It has a marked advantage over other types of dredges in working in exposed situations, as along a sea-coast, because its operation is not interfered with by the disturbance of the waves. It is so favorably adapted to excavating in sand and has had so great experience in this line, that it is frequently spoken of as a sand-pump dredger.

It cannot,however, excavate large boulders, or break them up, but perhaps this inability is not inherent to the system. The operation of the dredge is not economical when employed upon small work, because the preparatory costs are so high. A fault that is, however, inherent to the system is the fact that much excessive water must be pumped out with the material. Nevertheless, the fault cannot be remedied, as it is essential that the material be liquified.

The pneumatic dredger has, however, solved the problem of all excavators, that of excessive lift of the material. The lift of the dredged spoil is reduced to a minimum, as the discharge pipes are capable of being placed at the level of the hopper gunwales.

The problem of determining which type of dredge to use

upon a piece of work is indeed extremely difficult. The type of dredge is always restricted by the existing conditions, such as character of the work, capacity, amount of capital available, purpose of excavation, and time available for performance of the work. The main consideration is, however, to select that type of dredge best proportioned to the capacity of the work that is to be performed.

CONCLUSION.

The problem of determining which machine to use upon a certain piece of work is one of extreme difficulty and of vast importance. A study of the conditions under which the machine must work should always be made before considering the operations and workings of the machine which is to do the work. All possible confronting obstacles must be considered so that if they occur they may be reckoned with in the most expeditious and economical manner. Failure to understand fully the numerous different items which would affect the working of the machine, has been the cause of failure in much excavating machinery. It is, however, not at all certain that a machine which has done excellent work under certain favorable conditions would not be a failure if some of these conditions were even slightly changed. And, in order to determine what machine is best adapted to any particular circumstance, it is necessary to understand fully all the conditions under which the machinery must operate. The character of the material which is to be handled, and even the class of men who will be employed to operate the mechanism,must be considered. Hence it may be said that the first duty of the contractor is to study thoroughly the conditions of his work and, secondly, the advantages and disadvantages of the various machines,before he attempts to choose the machine which is to do his work.